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Conceptual Foredesign of Functional Systems

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Abstract

Today's fast-developing world requires a special method to the evaluation of future events. Conventional expert approaches often do not allow to obtain an acceptable result, since they use linear techniques that do not take into account the emergence of new technologies.

For this purpose, in contemporary TRIZ there is a section that includes the trends of functional systems evolution. But the existing ways to work with trends, unfortunately, are not sufficiently algorithmized. So, it is necessary to rely either on intuition, or on passing through all conceivable options of changes. This makes it very difficult to evaluate ideas, and can lead to the fact that some of the ideas will be missed.

In the paper a systematic algorithm for conceptual foredesign of functional systems is offered. The algorithm is based on:

(1) conceptual modeling of real objects as functional systems;
(2) triple analysis of the models with decomposition of form, structure and functions;
(3) life cycle analysis of considered systems and evolutionary cycle analysis of systems as classes;
(4) analysis of functional super-systems and the immediate environment as well as stakeholders.

A visual representation of the structure of key trends of systems evolution and the principle of their application to the modification of functional systems are also considered.

Keywords: conceptual foredesign, evolution trends, forecasting, functional system, S-curve, TRIZ.

1. Introduction

Innovation process in technology advancement requires continuous methodological support. Forecasting is one of the most important areas of such activity. Innovative activity planning is carried out on the basis of forecasts. At that, results of such forecasts should be sufficiently stable for systems of any type.

Attempts are repeatedly made to predict the future in different areas of the national economy. An example of one of such early predictions is presented in the work by Thomson (1955). There are various forecasting methods in the main areas of human activity. All these methods are aggregated in such discipline as prognostics, and they can be divided into two large groups: (1) regulatory and (2) research or pioneering methods.

Regulatory forecasting is rather the projection activity based on the existing technologies. Research forecasting can be divided into the following types:

- expert approach (e.g. Delphi method);
- assessment of future events through extrapolation of the existing technology development trends – this approach is, in fact, continuation of the regulatory forecasting and implies that the current development trends of any system will continue in the future;
- group sessions on compilation of the development roadmaps through brainstorming (foresight techniques).

But, in general, they all rely on knowledge and intuition of the experts or on insights of the brainstorming participants. Lack of scientific approach leads to situations when trivial ideas are most often accepted while promising original ideas can be discarded. A forecast based on extrapolations of the obvious trends can produce relevant results only at short-time intervals and does not account for fundamental transitions in the system development leading to breakthrough innovations.

Moreover, forecasts are more typical for random events which laws of variation we do not know (yet). This may be, for instance, natural or even social phenomena. When it comes to technical systems or enterprises, controllability is rather high here which means that it is possible to directly design the future generations' systems. Foredesign is aimed at solving this problem by minimizing risks of linear forecasts.

Foredesign, though related to forecasting, is based on TRIZ methodology, conceptual modeling and trends in functional systems development, which rest on laws of the dialectics. Therefore, such approach can be used as the basis for designing (not forecasting) future systems.

2. Background

Before proceeding to consideration of algorithm for conceptual foredesign of new functional systems, it is necessary to look into the basic concepts: functional systems (FS), mechanism of FS development – and rules of work with them. These concepts will be briefly presented here with references to the sources describing them in more detail.

(2.1) Target object modeling

One of the objects of study in science of creativity and contemporary TRIZ is reality objects. The subject here will be functional systems, rules of their construction and transformation as well as mechanisms of their development. Another object is individuals. Here the subject of study will be productive thinking with rules of its development and application. Schematically it can be represented as follows (**Fig. 1**).

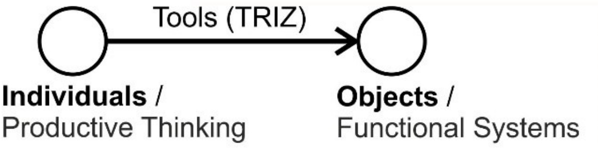

Fig. 1 Representation of the main objects and subjects of study in science of creativity and their relationship in the form of algorithmic approach.

Within framework of the proposed algorithm, it is necessary to build functional system architecture (**Fig. 2**) using object modeling at the upper level with selection of the key functional elements (functional subsystems). These elements provide functional flow for implementation of the main useful function.

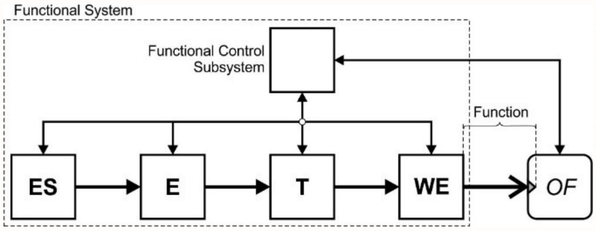

Fig. 2 Architecture of executive level of functional system; *where ES – Energy Source; Converters of Energy: 1st kind – "Engine" (E), 2nd kind – "Transmission" (T); WE – Working Element; OF – Object of Function.*

Object model can be recognized as functional system under the following conditions:

- The system executive level architecture contains efficient elements as energy converters.
- Elements are interconnected and provide for conversion and free flow of energy from energy source (ES), through working element (WE), to object of function (being part of another FS).
- Functional control system is available (external or as subsystem of the target system) – exchanging energy, serving an information carrier, with FS elements and with function object. When designing the system, it is sufficient to ensure minimal controllability – with possibility of turning the energy flow on and off.

Modeling allows to cope with complexity that arises when considering the target object, and, in the future, to achieve better situation understanding with analytical tools. Modeling objects as functional systems and other important definitions were proposed in the author's previous work (Smirnov, 2018).

Besides, element-functional model of the object (see **Fig. 2**) is universal – specialists in any sector of the national economy can use it in practice.

Below, emphasis will be placed on trends of functional systems evolution and methodological tools for their application through productive (creative) thinking.

(2.2) Trends of functional systems evolution and its structure

What trends does evolution of functional systems follow? Both the first trends and machine structure version (analogue to FS) were proposed by Marx (1906 [1867]). Marx described the following trends: mechanization, development of energy source, increased number of working elements; and he wrote about the machine structure: "All fully developed machinery consists of three essentially different parts, the motor mechanism, the transmitting mechanism, and finally the tool or working machine".

In the framework of classical TRIZ these trends were broaden based on patent analysis and available technical solutions (Altshuller, 1979). Many variations of these trends exist today, though mainly in the form of disconnected "lines", for instance, in the works (Altshuller et al., 1989, Mann, 2003, Shpakovsky, 2006). Such representation does not give new quality.

However, unique relationships and regularities in the trend application sequence can also be highlighted. For example, to increase system controllability, engineers are to prepare it for this stage: it is necessary to add transmission (executive level deployment), increase dynamization of the existing links, match new elements with those already present in the system, etc.

Thus, it is possible to determine approximate time intervals of trend application start within evolutionary cycle of classes of systems which will allow to more accurately determine systems development potential. It is most convenient to make such representation on S-curve distributing – very approximately – available basic trends of functional systems development by evolutionary stages. This will allow engineer to see the priority sequence of their implementation. All trends have many sub-trends – mechanisms to support their implementation.

The S-curve is plotted as relation of value and time (**Fig. 3**), which reflects character of development of functional systems tending to increase value (or degree of ideality). The first version of such approach was published earlier (Smirnov, 2007).

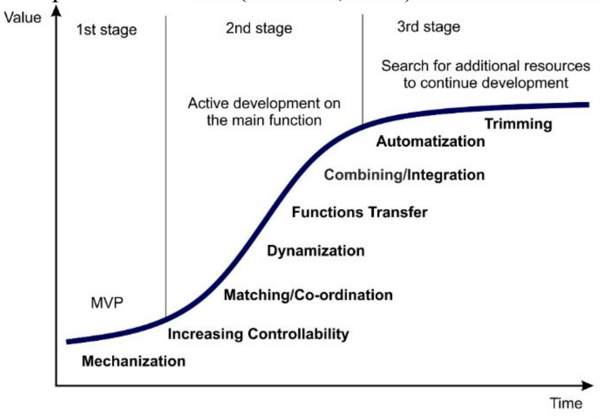

Fig. 3 S-curve with primary trends.

The first stage is characterized by appearance of the system as a class and its formation. It is necessary to ensure stability of the system through presence of all key elements and maintaining their joint work aimed at fulfillment of the system main useful function.

If the system is not yet available and only an individual performs all functions, the system will start with mechanization – introduction of artificial working element (WE). Further, the system deployment (complication) continues at executive level – with human action replacement by technology.

If new system relies on a prototype at birth, then the first evolutionary stage is usually linked to change in operating principle of one of the key functional elements at executive level of the prototype – energy source, engine or working element (revolutionary transition – jump to next S-curve). So, it is necessary to check ratio of "technical" elements and those which functions are performed by an individual.

Functional deployment results in necessity to increase controllability and to check matching of new elements with the existing structure and supersystem conditions. This can be done in various ways, for example, through dynamization of basic entities: elements and functions.

By end of the second stage, time for automatization comes – deployment at control level. Qualitative transition starts – to increased controllability through human action substitution by technology at this level. Decision-making function is also transferred to automatic machinery.

The third stage is usually associated with more active interaction of the system and its environment. In particular, at this stage combining of systems takes place, also named "transition to the supersystem". But if the supersystem is already defined, then the system belongs to it, anyway – that is, being its element or subsystem. Then, what does this "transition" mean in this case?

To interpret these principles more accurately the following division makes sense: (1) transferring the functions up a level to the supersystem (for example, when instead of teaspoon, sugar cubes in tea are mixed by mechanism built into the mug); (2) combining systems that are not in hierarchical relationship with each other (for example, fork and spoon can be combined – these are the same level objects) with partial trimming; (3) integration with promising systems being at the first stage, which makes it possible to obtain new resources for further development (for example, conventional glasses with addition of face recognition function).

Active development of functional systems (steep part of S-curve) leads to increase of number of components (complication) and to accumulation of errors, which can be corrected with the use of special tools: functional-ideal modeling and trimming. Also, development process is uneven for different FS elements. At initial stage more attention is paid to WE, which leads to its advancing development. After that, efforts and resources are transferred to pull up remaining elements. But how is it possible to use such approach in the context of improving functional systems?

(2.3) Applying trends to functional systems

Based on the above, option of direct application of trends to system elements is obvious. Shpakovsky (2006) proposed similar technique, but in his work there is no tools to justify choice of trends and there is no procedure for its application. In addition, direct use of combinatorics can lead to huge number of transformation options, which will make it difficult to evaluate them and choose the most promising ways to improve functional systems.

Reason for lack of such tools is that functional structure of the systems, although available, is not used in practice to the full because functional approach was not sufficiently developed within the framework of classical TRIZ. Direct use of well-known trends in relation to the technical system main parts is presented in the work 'Trends and patterns ...' (Leon, N, 2006). However, functional approach is not used here, as in many other works, and there is no procedure for working with the table. All this leads to situation when this topic, though important, lacks for further development in practice.

Nevertheless, when using system-functional approach, it is possible to build effective morphological table. It is proposed to use simplified combination: to apply the primary trends (see **Fig. 3**) for the main entities of the target object model – FS (see **Fig. 2**). Scenario of combining FS architecture and the primary trends is shown in **Fig. 4**.

	→	ES	→	E	→	T	→	WE	→	OF
	in/F	*El/OP*	*F*	*El/OP*	*F*	*El/OP*	*F*	*El/OP*	*MF/out*	*El*
Mechanization										
Controllability										
Matching										
Dynamization										
Functions Transfer										
Combining										
Automatization										
Trimming										

Fig. 4 Selection table for FS development strategies; *where F – Function; MF – Main Function; El – Element; OP – Operating Principle.*

Practical application of the presented morphology is possible after functional system analysis described below.

3. Algorithm for Conceptual Foredesign of Next Generation Functional Systems

Proposed morphology (see **Fig. 4**) is the final stage of triple (value) analysis, element-functional analysis and FS evolutionary analysis.

This algorithm can be used to achieve the following goals:

- for "pure synthesis", in the absence of a direct prototype;
- for designing system modifications – for different operating conditions and different needs;
- for designing new generation systems – this option is also named "forecasting".

Step 1. Selecting object for consideration

First, it is necessary to set boundaries for situation consideration, since initially only target is available in the form of general description of inconvenience or desire to do something with object under consideration.

If it is entrepreneur who formulates the target, then it can be something like this: it is possible to make bottle caps of any shape, but it is necessary to beat competition and surpass similar products in key product features (KPF) ensuring high product value for consumers.

It is assumed that the prototype is selected. On the one hand, existing solutions cause a number of psychological barriers associated with action of mental inertia of thinking according to the following features (habitual): form, function, operating principle, terms (names), sequence of operations, etc. All this complicates transition to new product versions.

On the other hand, prototypes are triggers of a kind for our thinking that allow thoughts to push off from them and go further. Not coincidentally, progress is incremental, step-by-step: the more objects been created world over, the newer objects (products) can be obtained. For this, it is only necessary to learn to cope with factors that are on the "first hand".

If, for any reason, there is no prototype, it is possible to either choose the most effective alternative system by the key feature or to build the most general element-functional model of the object and the main external interactions based on required system functions.

Step 2. Object modeling and analysis

To start with work on achieving one of the three goals described above – improvement of selected object or synthesis of new one – it is necessary to make model of this object in FS form (see **Fig. 2**), components of which ensure realization of the main useful function at usage stage of the life cycle. If necessary, it is possible to consider other stages of the life cycle of certain system starting with production.

When disadvantages are identified, element-functional models of conflicts will be made, and tools to eliminate these conflicts will be selected (see Step 3 below).

When system is complex, triple (value) analysis is required which will allow to better understand the made object model and to localize conflicts.

If there are many conflicts or there is time-or-space coextensive process, it makes sense to carry out cause-effect analysis and/or flow analysis. This will not only reveal all conflicts but also identify the key ones.

Further, it is possible to formulate problem in more functional terms, for example: it is necessary to develop special cap containing vitamin powder for standard bottle ensuring vitamin easy migration to still drinking water contained in the bottle.

Step 3. Revealed conflict analysis

During model analysis new conflicts may be found out. It is necessary to localize such conflicts and to build element-functional model for each of them (Smirnov, 2016) with further model analysis.

In case of contradiction of conditions, it is necessary to switch, for instance, to ARIZ-85C, which will, recommend solving the so-called "mini-problem". This is relevant if there are constraints or resources are insufficient, and new functional system has to remain within bounds of the previous operating principle. The maxi-problem will be connected with change of the condition in contradiction of conditions.

Step 4. Identification of external functional relations

Here, relationships with other systems and nonsystematic external factors should be taken into account. For this, it is necessary to select stages of the system life cycle on which attention will be focused.

(4.1) Selection of supersystems

The main process, in which the system participates at usage stage, is selected. Such process will play role of functional supersystem for the first system. Another device, integrating the considered system, can also play supersystem role. For example, for vitamin drink, morning run in park can be the supersystem.

(4.2) Building system hierarchies

Functional elements of the improved system (Step 2) will act as subsystems, and the processes or devices highlighted in Step 4.1 will act as the nearest supersystems. All together, they form system hierarchy (or vertical) for given function.

When several life-cycle stages are considered, it is also possible to build system operator of life-cycle (SO.LC). Unlike system operator of evolutionary cycle (SO.EC), which will be built below, this structure relates to certain system and reflects the path that the product travels from production to disposal or recycling.

(4.3) System hierarchies analysis

For each stage of life cycle the system will have its own functional supersystem. This gives additional understanding of the system, its role in various processes and new ideas. For example, ideas that vitamins can be in other (besides powder) forms – they can be not in the cap only, but also in user pocket or glued to the bottle, etc. Is it possible to change supermarket shelf – to make it functional, customized for product type displayed on it? Then the shelf itself will activate the vitamin drink for buyer.

System operator also helps to evaluate the following:

- functional interest of stakeholders and their position in relation to the system;
- remaining external relations, including non-obvious ones, through functional driven search;
- available and possible drivers (requests, needs, market and technology trends) and constraints "from below" and "from above" (**Fig. 5**).

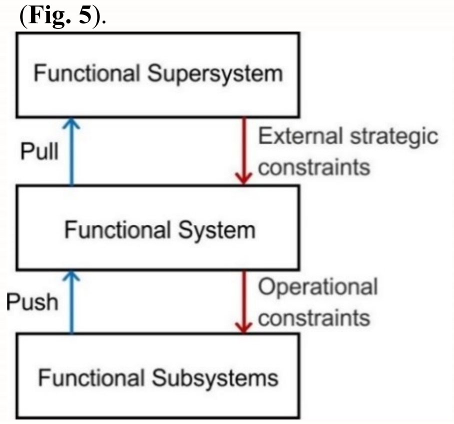

Fig. 5 System hierarchy with evaluation of drivers and constraints.

Pull "from above": it is necessary to evaluate the supersystem request (motivation) for the system change and to search for resources required for implementation of these changes and support of system development. External strategic constraints: it is necessary to verify prohibitions or barriers for manufacture, distribution or usage of the product. Push "from below": what stimulates product market launch if there is no direct demand for it? Operational constraints: what are technological challenges for manufacturing new system?

Thus, demand (supersystem requirements) "pulls" the functional system into high-value area. The system built-in capabilities, including use of new materials, new operating principle and other trends – "push" the system to the same area of increased value. In contrast, external and internal constraints hold on these processes (see **Fig. 5**).

Step 5. Evolutionary analysis

Evolutionary analysis is carried out using S-curve by defining ideal representation of functional system as landmark, and applying development trends as guidelines to ideal image.

To evaluate the past experience of system class development, it is necessary to carry out retrospective diagnostic analysis of its evolution. This will allow to estimate development potential of today's system. After that, it is possible to make the most accurate recommendations for designing the next stage system or even the next generation system.

(5.1)Determination of evolutionary stage in system development

Evolutionary stage determination will allow to understand which trends need to be applied first. To do this, it is required to know by what criteria to correlate the system and stages of development.

Stage indicators:

1st stage. There are single working samples, but there is no mass product on the market. End of the first stage can be described as “question mark” or “problem child” according to the BCG matrix.

2nd stage. Active market seizing and introduction to various areas of people's lives. In the second part of this stage the product can be named “star” in case of seizing high share of fast-growing market.

3rd stage. The product holds stable position in low growth market. This is “cash cow”.

4th stage. The product moves into narrow niche or leaves the market being forced out by new generation product. This product is “dog”.

Example. Today drinks with smart caps are exactly at this stage – slipping past the second and third stages they moved to the fourth stage and became a niche product with small market share awaiting the opportune time, that is – resources for more active market entry. There are at least two reasons for this behavior: high cap design costs and market appearance of vitamins, which can retain their quality in water for a long time.

(5.2) Construction of system operator of evolutionary cycle

System operator of evolutionary cycle will rather relate not to a certain system but to a class of systems. Here, for the present time, the system hierarchy will coincide with the system hierarchy for the usage stage (by main function) of the system life cycle (see Step 4).

Construction of system hierarchies for previous generations of the system allows for the first estimated assumptions for further system development. To do this, it is necessary to perform diagnostic analysis of transition from the past system to the present-day system. Further, the same techniques, which stimulated the system development at that time, will be applied. However, the necessary condition for such approach is presence of similar type conflicts in both systems.

(5.3) Selecting landmark in system development

Since it is not always possible to know the system desired future state, it is convenient to build its functional-ideal image right away.

Based on the formula: Value ~ Functionality/Cost, – ideality is achieved by striving value to infinity.

The maximum value for the system can be obtained in several ways by changing the ratio of functionality and costs. For example, this can be achieved through elimination of harmful functions, normalization of inadequate functions, addition of new relevant functions or even through increased manufacturing costs with significantly greater increase in functionality, etc.

It is also convenient to identify ideal representation of the target functional system for each selected stage of the life cycle. This representation will depend on the main functions and results to be obtained at each such stage. For example, the ideal system at transportation stage – with a minimum volume and weight; at stage of “demonstration” on supermarket shelf – with additional functions to attract attention of the target audience; at stage of vitamins activation – with minimal user time needed for learning and implementation; at disposal stage – completely missing bottle and cap.

(5.4) Using guidelines to ideal image

At this step of evolutionary analysis, the system evaluation is envisaged at selected stages of the life cycle by degree of approximation to the ideal images. This can be conveniently done by comparing “path covered” with limit of development according to the primary trends (see **Fig. 3**) for all entities included in the functional system architecture: elements, functions, connections. It is better to perform such evaluation visualizing results with the use of graphs such as Radar Plot, for example.

Trends are sequences of recommended transformations of the above entities in direction of functional systems value (degree of ideality) increasing. Such transformations are easy to perform according to the scheme proposed in **Fig. 4**. Table of choices for FS development strategies can be filled in the following way: (1) to make necessary basic transformations, (2) to evaluate results of transformations and choose strategies for further work, (3) to draw plan of work with selected strategies –

through formulation of tasks and their distribution between the innovative project participants.

Similar tables, if necessary, can be built for the control subsystem, and, if there are no restrictions in the task conditions – for the FS-“product” on the side of the function object, which plays the working element role in the system architecture.

Step 6. Evaluation of results

Transformations can lead to conflicts with system stakeholders. To eliminate conflicts, it is necessary to use special principles and algorithms in case of single problem functions (Smirnov, 2019), and more complex analysis-synthesis tools in presence of contradiction of conditions (see Step 3).

Influence of changes in the system on different spheres of public life can be examined with special classifications used in foresights, for instance, STEEP or EGETEC.

It is also possible to carry out an inverse analysis, for example, Anticipatory Failure Determination, to check stability of the obtained solutions to various random factors that may be present in the environment where the new system will be after manufacture – this relates to the specific system life cycle.

It remains to perform ranking of the selected concepts by effectiveness and feasibility based on overall situation in the sphere which the system belongs to as well as drivers and constraints available by the moment of decision making (see Step 4.3).

4. Summary

The principle of conceptual modeling of objects, and the algorithm for designing functional systems were introduced. This algorithm is convenient to use as a checklist in a new product development (NPD) process. A brief block diagram of the conceptual foredesign of functional systems is shown in **Fig. 6**.

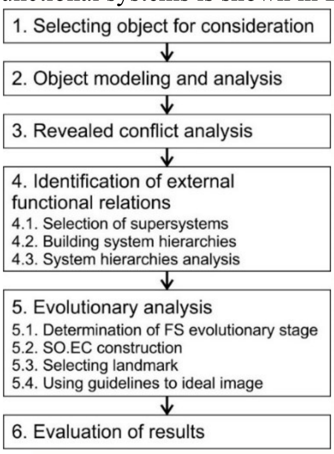

Fig. 6 Algorithm for conceptual foredesign of functional systems block diagram.

The proposed conceptual foredesign of new systems is based on the following theses:

(1) It is necessary to use functional approach in building the system architecture – this makes it possible to use it in practice.
(2) If the structure is fairly complex, it is necessary to use preliminary triple (value) analysis of the system for better understanding and localization of hidden conflicts.
(3) Localized conflicts are to be modeled and resolved by applying special rules to these models.
(4) The systematic analysis shows points of concentration of engineering efforts.

This approach makes it possible:

- to design new systems, which includes predicting emergence of new operating principles;
- to obtain multiple patents and create "patent umbrellas" taking into account all the most promising modifications of future systems;
- to determine enterprise development strategies by creating a powerful vision for change.

5. Conclusions

Element-functional modeling makes it possible to work with objects of any nature, representing them as functional systems of various types: technical, informational, social, organizational, including business-systems, that differ only in the degree of controllability.

To successfully use the tools of contemporary TRIZ, it is necessary to design thinking for creativity (see **Fig. 1**). The educational process didactics is largely responsible for it. To increase the efficiency of thinking to improve both products of companies and companies themselves, in addition to knowledge of tools, it is necessary to take into account factors consistent with the laws of dialectics, which were proposed to describe the mechanisms of nature development (Engels, F., 1940 [1878]): psychological readiness for groundbreaking [the law of the negation of the negation]; ability to work with contradictions [the law of the interpenetration of opposites]; need to evaluate the magnitude of any changes and the possibility of breakthrough innovations [the law of the transformation of quantity into quality and vice versa].

This study has introduced a tool for new product development based on contemporary TRIZ methodology that is holistic, although not easy to use.

But this approach will allow companies to create new products without missing any key solutions.

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A Crowdsourcing Data-Driven Approach for Innovation

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Abstract

Creativity is an essential element of innovation, but producing creative ideas is often challenging in design. Many computational tools have been developed recently to support designers in producing creative ideas that are new to individuals. As a common feature, most of the tools rely on the databases employed, such as ConceptNet and the US Patent Database. However, the limitations of these databases have constrained the capabilities of the tools. Thereby, new computational databases for supporting the generation of ideas that are new to a crowd or even history are needed. Crowdsourcing outsources tasks conventionally performed in-house to a crowd and uses external knowledge to solve problems and democratize innovation. Social media is often employed in crowdsourcing for a crowd to create and share knowledge. A novel approach employing social media to crowdsource knowledge from a crowd for constructing crowd knowledge databases is proposed in this paper. The crowd knowledge database is expected to be used by the current computational tools to support designer producing highly creative ideas, which are new to the crowd, in new product design, and ultimately leading to innovation. Challenges of employing this approach are discussed to provide insights and potential directions for future research.

Keywords: Creativity, crowdsourcing, data-driven design, innovation, social media

1. Introduction

Creativity is connected to innovation via design (Han et al., 2018a), while creativity is often associated with idea generation. Idea generation, also known as ideation, is the process of coming up with ideas during the early phases of design. It has been considered the foundation of innovation (Cash & Štorga, 2015; Sarkar & Chakrabarti, 2011), which is also a significant element in business success (Howard et al., 2011). Therefore, generating creative ideas is essential for achieving innovation. However, it is always challenging for individuals to produce creative ideas, due to limited knowledge, many existing ideas, time pressure and lack of creative mind (Han et al., 2018a). Knowledge is a significant resource in supporting innovation (Bertola & Teixeira, 2003) but it is difficult and time-consuming to collect information and knowledge for assisting idea generation. Ullman (2010) indicated that design engineers spend 60% of the time during the design process to explore the information and knowledge needed. Therefore, to support designers in creativity and leading to innovation, relevant knowledge or a database containing the needed knowledge needs to be provided to designers.

There is a growing interest in using computational tools for supporting designers in generating creative ideas in recent decades. Databases, containing knowledge for supporting design, are often employed by the tools. Various databases are used, for instance, design repositories, ConceptNet, biological and engineering systems in structure-behaviour-function forms, and customised ones. However, some databases involve a limited amount of knowledge, some are not suitable for design, and some mainly contains past knowledge. Besides, new knowledge emerges rapidly in nowadays fast developing world. To produce creative ideas for developing nowadays innovative products, up-to-date knowledge is needed. Thereby, it is needed to explore how to employ rapidly emerged knowledge to support designers in creativity and innovation. Crowdsourcing is a model where many solutions are generated by answering open calls. Goucher-Lambert and Cagan (2019) have shown the use of crowdsourcing to generate inspirational stimuli to support idea generation. Social media is described as 'a group of Internet-based applications that build on the ideological and technological foundations of Web 2.0, and that allow the creation and exchange of User Generated Content' (Kaplan & Haenlein, 2010). Thus, social media, such as Twitter and Facebook, are considered platforms which are often used by crowds for creating knowledge. Taking the advantages of crowdsourcing and social media, databases containing up-to-date knowledge created by the crowd could be constructed.

The authors of this paper aim to explore a crowdsourcing data-driven approach to construct crowd knowledge databases for innovation through supporting creative idea generation. In the approach, social media will be used as platforms to crowdsource knowledge for producing the databases. The crowd knowledge databases are intended to be employed in existing computational creativity tools for improving the tools' performances and capabilities. This will benefit the generation of creative ideas and lead to innovative products. Creativity in design is investigated in the next section. Crowdsourcing and related frameworks are explored in section 3 and 4, respectively. Based on the explorations, the crowdsourcing data-driven approach is proposed in section 5. Challenges involved in this approach are discussed in section 6, and the paper is concluded in section 7.

2. Design Creativity

Creativity is considered a significant element in design, which is defined as the process of producing something judged to be creative (Amabile, 1983). Han, Forbes and Schaefer (2019) have indicated that novelty, surprise, and usefulness are the three core factors of creativity in design. Idea generation involves the process of creating developing and communicating ideas, where ideas are fundamental elements of thoughts in visual, concrete and abstract forms (Jonson, 2005). Idea generation has been considered essential to innovation (Cash & Štorga, 2015; Sarkar & Chakrabarti, 2011). However, idea generation, especially generating creative ideas, is a challenging process in new product design and development.

Creativity tools and methods are thereby developed and used to support designers in creative idea generation during the early stages of design. There exist two categories of tools for supporting creative idea generation, non-computational and computational tools. Non-computational tools, such as TRIZ (Altshuller, 1984), design-by-analogy (Goldschmidt, 2001) and the 77 design heuristics (Yilmaz et al., 2016), provides designers with guidelines and instructions for producing creative ideas. However, some of the tools rely heavily on designers' knowledge, while some others are challenging to master.

In recent years, computational tools which involve the use of computational techniques for supporting idea generation have been explored. These tools could produce creative prompts and provide relevant knowledge to support designers in creative idea generation more effectively and efficiently. The Retriever (Han et al., 2018b) prompts designers in generating creative ideas through constructing new ontologies to support reasoning by employing real-world data. The database employed in the tool is the ConceptNet (Speer et al., 2017), which is a machine-understandable knowledge network. The knowledge contained is mainly common-sense knowledge, which has limited the Retriever in constructing highly novel ontologies for supporting idea generation. Analogy Finder (McCaffrey & Spector, 2017) provide users with adaptable analogous ideas for solving technical problems by conducting searches using the US patent database. However, the tool requires the users to have strong expertise and knowledge to adapt the ideas retrieved from the US patent database employed for solving problems. Idea Inspire 4.0 (Keshwani & Chakrabarti, 2017) designers in generating creative ideas for solving problems via analogical design. A searchable knowledge base is employed in the tool containing a limited number of biological systems. An automated approach has been proposed by Keshwani and Chakrabarti (2017) for populating the database.

Creativity has been classified into two main categories, H-creativity and P-creativity (Boden, 2004). H-creativity refers to historical-creativity, which indicates generating ideas that are new in history. P-creativity, also known as psychological-creativity, indicates producing ideas that are new to the person who produced the idea. Comparing with the design creativity studies at P-creativity levels, fewer studies focus on H-creativity levels. Therefore, there is a need to explore design creativity at H-creativity levels, investigating how to produce ideas that are new to a group of people, a crowd and ultimately history. From a group perspective, studies, such as the ones conducted by Paulus and Dzindolet (2008) and Nijstad and Stroebe (2006) have shown that collaboration has positive effects on creativity. Paulus, Dzindolet, and Kohn (2012) have revealed collaborative creativity could produce better outcomes than individual creativity. This indicates that using groups could produce ideas that are better than the ones produced by individuals. Ideas produced by a group are new to the group, which are beyond P-creativity and close to H-creativity. Thereby, employing an even larger number of people, such as a crowd, could potentially lead to the generation of ideas that belong to the H-creativity category.

As illustrated above, databases play a significant role in nowadays computational tools. However, the databases employed by the tools have various limitations, which have negative impacts on the tools' capabilities. Besides, the use of a crowd in supporting design creativity, especially creative idea generation could yield superior results. A crowd could be employed to produce ideas or provide knowledge for solving design problems. The ideas produced and knowledge provided by the crowd could be constructed into a crowd knowledge database to support designers in producing creative ideas to solve the design problem. Thus, a new approach to create crowd knowledge databases for computational tools to support designers in creative idea generation needs to be explored.

3. Crowdsourcing for Innovation

Crowdsourcing is described as a web-based creative problem-solving model, in which "a distributed network of individuals produces solutions to an open call for proposals" (Brabham, 2008). In the context of design, Forbes and Schaefer (2018) suggest that crowdsourcing is most suited to evaluation and ideation, as shown in **Fig. 1**. Later design phases require a higher skill level and are therefore are harder to "open to the crowd". The suitability for ideation and other early design stages, therefore, is as a consequence of the inverse relationship between the size of the qualified crowd and the level of skill for contribution. For example, in concept generation, "ideas are not scrutinised on their technical rigor or feasibility" (Daly et al., 2012; Forbes et al., 2019). The number of those qualified to make these contributions is higher than later design phases and therefore the crowd available in this phase is large. This is, however, founded on the assumption that a larger number of contributions results in a more successful crowdsourcing initiative. Panchal (2015) discusses several "modes of failure" for crowdsourcing initiatives, including "a lack of submissions" but also the result of "numerous poor-quality submissions". It is important to consider, therefore, that while we make the assumption that higher number of submissions is preferable, it is possible that too many submissions can be detrimental to the success of the crowdsourcing initiative.

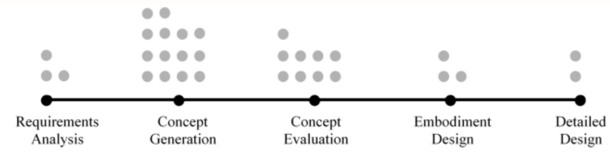

Fig. 1 Current literature's exploration of crowdsourcing in each product development phase (One grey dot represents one source) (Forbes & Schaefer, 2018)

Examples of initiatives that use crowdsourcing for idea generation includes Goucher-Lambert & Cagan (2019) who have used crowdsourcing techniques to "obtain inspirational stimuli" to support designers in ideation. "Connect and Develop" from Procter and Gamble, is another example described as an "organisation partnership" with "the world's most innovative minds". As part of Connect and Develop, Procter and Gamble encourage the crowd to submit product ideas and suggestions according to a theme most relevant to their organisation at the time (Dodgson et al., 2006). Since using crowdsourcing for idea generation, Procter and Gamble's R&D productivity increased 60% and 45% of new initiatives had elements discovered externally (Dodgson et al., 2006; Forbes et al., 2019). A final example is the DARPA crowdsourcing initiative which awarded one million dollars to a design team, external to the organisation, for the creation of an "innovative marine tank drive train" designed to significantly improve efficiency of tank movement (Ackerman, 2013). Crowdsourcing has therefore been demonstrated as a success in many idea generation initiatives (Forbes et al., 2019). Including the crowdsourcing process as an element of a data driven approach for design creativity, whereby formalising this process, could therefore prove useful to designers.

There are two types of crowdsourcing; active crowdsourcing and passive crowdsourcing. Active crowdsourcing is leveraged when the crowd actively participates in a contest or call for submissions. There are four types of active crowdsourcing initiative; crowdsourcing contests, open calls with direct rewards, open calls with direct rewards and micro-tasking. Table 1 below gives definitions and examples of these crowdsourcing initiatives.

Table 1 Active Crowdsourcing Initiatives (Panchal, 2015)

Initiative	Example	Description
Crowdsourcing contests	Gold Corp "Global Search Challenge" (Brabham, 2008)	Participants from around the world were encouraged to ex- amine geologic data from Goldcorp's Red Lake Mine and submit proposals identifying potential targets where the next 6 million ounces of gold will be found. $500,000 in prize money was offered to the 25 top finalists who identified the most gold deposits. (Brabham, 2008; Corp, 2001)
Open calls with direct rewards	Procter & Gamble's Connect & Develop (Dodgson et al., 2006)	
Open calls with in- direct benefits	Dell Idea Storm	In a similar setup to Connect & Develop, Dell Idea Storm seeks ideas on their website from a community of non-experts. Contributors, however, are not rewarded financially and instead benefit indirectly from the company's implementation of the ideas in their products (Di Gangi & Wasko, 2009)
Micro-tasks	Amazon Mechanical Turk	Amazon Mechanical Turk is a website that allows businesses to hire participants "to perform discrete on-demand tasks that computers are currently unable to do." (Buhrmester et al., 2011)

Passive crowdsourcing, on the other hand, uses information from the crowd that is in the public domain, or that has been collected with permission from the crowd (Charalabidis et al., 2014). How the information is used is dependent completely on the methodology applied by the data collectors and is not influenced by the content of the data. An example of passive crowdsourcing is Netflix's use of customer choices, to supply film and TV recommendations.

Using crowd data to populate computational creativity tools is a hybrid crowdsourcing approach using both active and passive crowdsourcing. An open call with indirect rewards, an active crowdsourcing initiative, is used to encourage the crowd to share their ideas. A set method is then used to process the data for use in a computational creativity tool, representative of a passive crowdsourcing approach. Several other authors have implemented hybrid active and passive crowdsourcing approaches. For example, Janssen et al. (2017) use a hybrid approach to crowdsourcing for policy making. They state that "synergy can be created by combining both approaches. The results of passive crowdsourcing can be used for guiding active crowdsourcing to avoid asking users for similar types of input". Similarly, Charalabidis et al. (2014) uses a hybrid approach for policy making by "exploiting the extensive political content continuously created in numerous Web 2.0 [technologies]". Finally, Akshay et al. (2018) use passive and active crowdsourcing for monitoring video for critical events stating that this approach "increases the feasibility of deploying continuous real-time crowdsourcing systems in real-world settings". There is therefore evidence of using crowdsourcing and an active-passive crowdsourcing approach for innovation, in several fields of research.

Despite evidence of similar successful uses of crowdsourcing, some crowdsourcing initiatives are more effective than others (Panchal, 2015). Ineffective crowdsourcing initiatives may invite inadequate submissions that fail to reach the required quality. A crowdsourcing initiative can also become ineffective if the expense of running the initiative exceeds the cost of an in-house team (Brabham, 2008; Panchal, 2015). As a consequence, there is a need to frame crowdsourcing processes. In the following section, existing crowdsourcing frameworks are presented.

4. Crowdsourcing Frameworks

Crowdsourcing has emerged with the birth of the internet and with the ability to share information quickly and easily, worldwide. Social media has been a catalyst in this growth by facilitating and supporting users to create, share and edit information, as well as build relationships through interaction and collaboration (Mount & Martinez, 2014). Kemp (2019) reported that there are 3.48 billion social media users in 2019, which leads to millions of posts every minute (Forbes et al., 2019). When an open call crowdsourcing initiative is launched on social media, therefore, potential participants can be reached, and ideas can be submitted quickly and easily. Preventing crowdsourcing failure, when leveraging social media, requires a methodical approach. Before presenting a new crowdsourcing social media framework for computational creativity, the authors explored existing research in this area.

Crowdsourcing frameworks are most prevalent in the field of product design and development. Niu et al. (2019) present a framework for the application of crowdsourcing in product development, guiding the user through important crowdsourcing decisions. Panchal (2015) also presents a framework for the use of crowdsourcing in product development, providing a four-step approach to crowdsourcing application. This framework includes three key steps; selecting crowdsourcing initiatives, making design decision and incentive design. Panchal also provides further detail regarding "incentive design" by presenting a game-theoretic model for managing crowd participation. Similarly, Abrahmason et al. (2013) present an "Incentives Mix Framework" for understanding crowd participation and Cullina et al. (2016) and Gerth et al. (2012) provide in depth research on finding the "qualified crowd" in crowdsourcing contests. Finally, Kittur et al. (2011) consider the crowdsourcing of Human Intelligence Tasks (HITs) and "provide a systematic and dynamic way to break down tasks into subtasks and manage the flow and dependencies between them".

In other fields, few authors have presented a crowdsourcing framework for their domain. To and Shahabi (2018) propose a crowdsourcing framework for "protecting worker location privacy in spatial crowdsourcing", Liu (2014) present a "crisis crowdsourcing framework" for "designing strategic configurations of crowdsourcing for the emergency management domain" and Chen et al. (2009) present a "QoE evaluation framework for multimedia content". These authors represent the scarcity of crowdsourcing frameworks and demonstrates the relative youth of this research topic. By creating a crowdsourcing framework for creativity, and specifically computation creativity, is therefore a significant contribution in an emerging literature sector. Furthermore, existing crowdsourcing frameworks are, in general, at a low-level of abstraction, addressing and guiding small aspects of the crowdsourcing process as opposed to offering high-level support. For example, Cullina et al. (2016) discusses the need to understand crowd motivation in contests which is a single factor contributing to the successful implementation of crowdsourcing. By presenting a high-level, crowdsourcing framework for computational creativity, the authors are offering more holistic guidance for crowdsourcing application.

5. The Crowdsourcing Data-driven Approach

As illustrated in **figure 2**, crowdsourcing initiatives allow varied and numerous data points to be collected from the crowd. They are particularly effective in early design phases as the prerequisite skill level for participation in these phases is reduce, In this section, it is demonstrated how crowdsourcing could acquire knowledge from a crowd to support creative design activities in new product design and development, such as idea

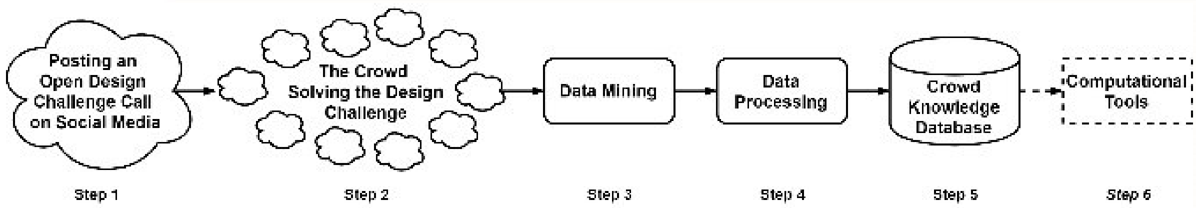

Fig. 2 The crowdsourcing data-driven approach of creating a crowd knowledge databased

generation and evaluation, by partnering crowdsourcing with computational creativity tools. A novel approach using social media to crowdsource design knowledge for creating crowd knowledge databases is proposed, as shown in **Fig. 2**. In step 1, an open design challenge call is posted on social media, such as Twitter and Facebook. A dedicated hashtag is involved in the open call post. The hashtag will help the crowd identify the open call on social media, as well as be used as a target to support the later data mining process. In step 2, an active crowdsourcing method is used to encourage the crowd to generate ideas using descriptive text for solving the design challenge in the open call. The ideas generated are posted back on social media containing the dedicated hashtag. Data mining is conducted in the next step to retrieve posts containing the dedicated hashtag only. This will help to discard noise data which are irrelevant to the open call. In step 4, the retrieved data are processed by using natural language processing tools to extract useful words and phrases. The extracted data are then used to construct crowd knowledge databases for supporting creativity and innovation in step 5. In the last step, the crowd knowledge databases constructed will be used by exiting computational design creativity tools to enhance the capabilities of the tools in supporting idea generation. For example, the databases could be employed by the Combinator (Han et al., 2018a) to produce combinational prompts associating knowledge produced by the crowd.

6. Discussion

Having presented the approach, this section considers the hurdles and challenges for implementation. There are three key phases of the approach that require attention. This includes, firstly, how participation will be encouraged and managed. Secondly, how the submitted responses will be processed is significant in determining the value of ideas generated from this crowd-knowledge database. Finally, it is important to determine how the submitted responses are included as part of the computational creativity tool and whether this should differ from other databases. The third phase, regarding use of the database, is managed by existing computational creativity tools but the first and second phases are included in the discussion (Forbes et al., 2019).

6.1 Managing Participation on Social Media

When considering the management of participation, social media allows access to the largest number of people possible which makes it an effective medium for hosting both passive and active crowdsourcing initiatives. The difficulty, however, is gaining active participation in on these platforms. “Social media is used extensively and constantly to attract attention and users can often be overwhelmed with online content” (Forbes et al., 2019). Enticing submissions therefore requires strategic thinking. In addition, high numbers are important but high variety is also important for generating innovative ideas (Howe, 2006). Organisations use crowdsourcing initiatives because they recognise a need to involve other perspectives beyond those of their in-house teams. Effort must therefore be made to increase exposure of the hashtag but while limiting the “echo chamber effect” that can reduce heterogeneity of the responses (Colleoni et al., 2014; Forbes et al., 2019). There is a need to manage how the hashtag is exposed to potential crowdsourcing participants to ensure text-based responses from users are effective for generating creative ideas.

Within crowdsourcing and creativity research domains, solutions to this challenge are limited. The authors therefore considered other research domains such as digital marketing to offer an understanding of how organisations can compete for social media attention while running a crowdsourcing initiative. To correspond with the required traits of captured data, the authors were interested in solutions to capture diverse information and solutions to capture numerous data. With regards to managing diversity, existing literature on the impact of social media on political preference, offered insight. Ensuring a heterogenous dataset, meant limiting the impact of “social media bubbles” or “echo chambers” (Zhan et al., 2016; Romero et al., 2011) which is of significant interest in the current political climate. Garimella et al. (2017) offer a solution that could be applicable to the use of crowdsourcing for computational creativity. They suggest when “exposing information” to users, a “symmetric difference function” could be “optimized” to limit the dominance of one piece of information in the case of two competing instances of information. In the context of ensuring diverse submissions, engaging a “symmetric difference function” could ensure that a single submission on the social platform would not influence subsequent submissions. Dubois and Blank (2018) also propose another solution which suggests the ownness is on the user to limit their vulnerability to polarising online content. They demonstrate that users with "diverse interests" on social media platforms are significantly less susceptible to exposure to polarising content. A solution to ensure heterogeneous submissions for a crowdsourcing activity, therefore, could be target users with connections with a range of interests and political viewpoints.

The authors were also interested in learning how a crowdsourcing initiative could "compete for attention" on social media platforms (Romero at al., 2011). Feng, et al., (2015) suggest garnering attention on "busy" social media platforms, information sharers need to understand how and when users become "overload with information" and respond accordingly. They show how information spread on social media can be represented by a fractional susceptible infected recovered (FSIR) model. In this case bacteria spread is analogous to information spread and infection presents information overload (Feng et al., 2015). Using this model, Feng et al. (2015) suggest spreading information early in the day and early in an "social information cycle" which they describe in detail. Iyer and Zsolt (2015) suggest that to compete for attention on social media platforms, information sharers must consider the incentives users respond to for social media use in general. They then suggest embedding these incentives, such as the ability to connect with others, into the mechanism they use to spread information (Iyer & Zsolt, 2015). Each of these existing solutions can be considered when implementing the crowdsourcing data-driven approach.

6.2 Processing a variety of information types

How the submitted responses will be processed is significant in determining the value of ideas generated from this crowd-knowledge database. Using texts to provoke the designers' mind in producing creative ideas has been demonstrated in a number of previous studies, but in various forms (Forbes et al., 2019). For example, Shi et al. (2017) employed network-based texts, while Han et al. (2018a) used combinational texts. However, the presentation form of the crowd knowledge, the solutions generated by the crowd and processed by computational means in this study, still needs to be explored (Forbes et al., 2019).

Collection of social media data differs from data (text) used in previous studies. Crowd data may include sentimental as well as emotionality aspects. This means that the process of natural language process must include a measurement of sentiment to determine the positivity, as well as negativity, of the whole text. Overall, emotionality needs to be calculated on individual text segments to indicate positive and negative text segments. Emotionality could support designers in decision-making by ensuring they have a greater understanding and further context of crowd data. For example, designers might need to avoid the design aspects related to negative knowledge and enhance design features related to positive knowledge (Forbes et al., 2019). This might also help the computational tools in a better comprehension of the crowd knowledge database employed.

The way social media users communicate has developed beyond just text-based, which should be considered, further, to processing emotional and sentimental aspects of participant responses, "Emojis", "GIFs" and "memes" are frequently and extensively used on social media to communicate ideas. Their use means either they must be filtered and removed, or "translated" for inclusion in a crowd database. One approach to this, as shown in **Fig. 2**, includes the use of key words to identify the key idea communicated in participant responses. It could be the case, however, that the key idea is communicated in a text-based caption with an image accompaniment to bolster, as opposed to convey, the idea. How this varying use of video and image-based content is managed should be taken into consideration.

Twitter and other social media platforms are purposefully designed to encourage collaboration and interaction between users. This results in functionality elaborating and "commenting" on other responses that is considered integral to the design of these online platforms. As a result, however, the processing of participant involvement needs to recognise not only individual responses including the hashtag but "clusters" or responses that all represent one idea (Forbes et al., 2019). As an example, one participant may include the "crowdsourcing hashtag" to present an idea which initiates an online conversation, with further responses elaborating on or supporting the initial idea. Some of these comments may be new ideas but others could be minor alterations of additions to the original submission. This means that including every response involved in the conversation and weighting them equally could disrupt the value of crowd data. An understanding of how collaboration occurs on social media is therefore fundamental to procuring valuable results for idea generation (Forbes et al., 2019).

Utilising crowd knowledge from social media shows great potential for supporting creativity and innovation. There are, however, several research challenges such as participation management and data processing, to overcome. Furthermore, the way social media users communicate has and will change to incorporate more media-based content. Further research is needed to solve these research challenges and recognise new opportunities in the applications of this crowdsourcing data-driven approach. The key next research step is to conduct a case study of using the crowd knowledge from a specific social media platform to solve a design challenge. The authors hope to provide more insights on this new and novel data-driven computer-aided innovation approach.

7. Conclusion

Generating ideas, especially creative ones, is significant to innovation. However, it is challenging to produce creative ideas. Many computational support tools are thereby developed to assist this process, but the current solutions are constrained by available databases. Lacking knowledge in terms of quantity and variety is one of the main issues of the databases. Besides, knowledge collection has been considered a time-consuming and frustrating activity. Crowdsourcing is a model for creative problem-solving which uses the knowledge produced by a distributed network of individuals also known as a crowd. Social media, which allows creating and exchanging contents created by users, is often employed to generate and share knowledge.

Thus, the authors of this paper have proposed a novel data-driven approach utilising social media to crowdsource knowledge to construct databases for computational tools in supporting creative idea generation, and ultimately leading to innovation. The databases constructed are called the crowd knowledge databases, which are populated by providing and distributing open design challenge calls with responses using unique hashtags for identification. Data mining and natural language processing are used in the construction process to retrieve and extract data, respectively. The crowd knowledge databases can then be implemented into existing as well as future computational tools to enhance their performances. Using the Combinator (Han et al., 2018a) as an example, the tool could associate crowd knowledge from the database to produce new combinational prompts, which are new to the crowd, for stimulating users creative mind. The data-driven approach proposed has implied its value of utilising some of the most used and data-rich platforms available to achieve innovation.

However, a number of challenges need to be solved to realize the crowdsourcing data-driven approach. In this paper, how to manage participation on social media and how to process a variety of information types are discussed. Several participation management methods, such as information spreading and incentives, as well as several information processing issues, such as sentiment measurements and collaboration understands, are indicated. Further research is required to explore these challenges and to overcome them, to fully employ the proposed crowdsourcing data-driven approach in computational support tools for innovation. This paper has thereby shown a new research direction in using crowdsourcing data to support innovation, contributing to the computer-aided innovation research area. The authors have planned to conduct a case study of solving a design challenge using the crowd knowledge from a specific social media platform, such as Twitter, in their next study to provide more valuable insights.

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The Role of Product Innovation and Flexibility as Competitive Priorities in Gaining Market Share: Empirical Evidences from Jordanian Manufacturing SMEs

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Abstract

This study aims at exploring the effect of product innovation and product flexibility as competitive priorities on increasing market share in Jordanian manufacturing SMEs. The study employs the quantitative design using hypotheses testing approach; Self administrated questionnaire is developed as data collection instrument. 270 questionnaires were distributed personally by hand to CEOs and Managers of SMEs in King Abdullah II Industrial City using stratified random sample. Statistical analysis such as frequencies analysis, simple regression, multiple regression, and ANOVA are calculated using SPSS to test the study hypotheses. The study concludes that there are positive effects of competitive priorities with its dimensions (product innovation and flexibility) on increasing marketing share. However, the effects are limited due to lack of employees' skill, shortages of funds, lack of research and development, and poor marketing activities.

The study recommends that manufacturing SMEs should focus on product innovation and flexibility as competitive priorities to enhance market share and confirm the edge needed for competition. To activate the role of product innovation and flexibility, management support and commitment is needed. Moreover, market research is a driver of new product introductions to adapt our SMEs products with changing environment.This is the first study that examines the role of product innovation and flexibility as competitive priorities in gaining market share in the Jordanian manufacturing SMEs.

Keywords: Product innovation, Product flexibility, Market share, Competitive priorities, Manufacturing SMEs, Jordan.

1. Introduction

Manufacturing SMEs have to consider different competitive priorities of their manufacturing activities that support business units to become more competitive to increase market share. Krajewski et al. (2013) divided manufacturing strategy into two dimensions such as order winners and order qualifiers; the order winners refer to core issues that are used by customers to select different products to meet market demand. Whereas, the order qualifiers refer to the complementary issues by customers such as time, flexibility, and warranty. The order qualifiers do not improve a competitive position for a company; it will just enable the business to survive in the market. Ibidunni et al. (2014) stated that product innovation is one of the essential strategies of growth that enables companies to enter and penetrate to new market segments. Product innovation can be used to gain the market share over competitors, and to improve a competitive position of the business.

Butt (2009) stated that manufacturing strategy dimensions have been developed through time and innovation. Moreover, product flexibility can be considered as a competitive weapon to adapt businesses with flux markets, dynamic environments, and fluctuating product life cycles. Awwad et al. (2013) stated that flexibility is a construct with different dimensions and it can be considered as a competitive weapon in any manufacturing or service business, especially in demand and productive capacity management to meet changes in customer needs, preferences, and expectations. In developing economies, they have come to realize the value of small and medium sized businesses. The contribution of SMEs is important in Jordan economy, due to the strategic role of SMEs in reducing unemployment ratios, and supporting market growth and demand size. However, in developing countries such as Jordan, there are many challenges for small businesses (Al-Weshah et al., 2011; Obeidat et al., 2017; ALManaseer et al., 2019). Therefore, the current study focuses on two major dimensions in manufacturing strategy. More specifically, product innovation and product flexibility as competitive priorities in increasing market share in Jordanian manufacturing SMEs

There are many competitive priorities for manufacturing SMEs. However, the current study investigates two main priorities; namely, product innovation and flexibility. Innovation is a critical dimension that creates opportunities to develop new products, improve current products, and penetrate new customer segments (Kuhn and Marisck, 2010; Altamony et al., 2012). Innovation helps firms in identifying their business problems, responding to unforeseen conditions, creating potential solutions of problems, and improving new ways to reach outputs, by using experience, skills, motivation and the organizational knowledge. These accumulated issues are converted into production of an innovative product or service (Miettinen et al., 2009). Ibidunni et al. (2014) stated that product innovation is one of the essential strategies of growth that used adopted by companies to serve new market segments, to gain the market share, and improve a competitive position of the business. Rosenbusch et al. (2011) identified several factors that affect the relationship between innovation and SMEs performance. They stated that new SMEs make more innovation than the mature organizations mainly due to their flexibility to accept change in their environment or industry. Moreover, Ibidunni et al. (2014) concluded that changes in customer's tastes and preference require product innovation, thus, product innovation increases sales volume of SMEs. Alam et al. (2016) stated that as SMEs face tremendous competition, innovation represents solutions to achieve many issues for businesses such as low cost and high quality; hence, innovation is a business strategy than can be used by SMEs to sustain and grow.

Flexibility is the products adaptation to customer needs and requirements of different changes. Flexibility also is the business ability to adapt to changing and dynamic business environment globally and locally in terms of time flexibility and customization flexibility; time flexibility is responding quickly to meet market needs through the induction of new products and services. Customization flexibility is to produce or provide services according to changing customer needs (Naqshbandi and Idris, 2012; Aldaas et al., 2019). Therefore, flexibility of products is the ability of a firm to launch new parts and products into the market to meet the changing customer environment.

In Jordan, SMEs play an important contribution in improving economic conditions, due to its strategic role in reducing unemployment rates and supporting market growth. More than 69% of the employees work in small and medium enterprises in the Jordanian private sector, with more than 90% of manufacturing firms is considered as SMEs, on the other hand, all retail and agricultural are SMEs. In developing countries such as Jordan, there are many barriers and challenges for investing and marketing in small businesses (Al-Weshah et al., 2011), such as cost of capital, inflation rates, government regulations and policy financing, globa l competition, and energy costs. In addition, Al-Weshah et al. (2013) stated that small and medium-sized enterprises (SMEs) have shown a greater uncertainty of the benefits of long-term relationships with customers that are essential in acquiring and maintaining a competitive edge in different organizations.

SMEs cannot only rely on their past success of existing products; they have to assess potential changes in customer's taste and preference, which are fundamental requirements for improving competitive positions. SMEs and lack of healthy competition in the sector lead to many problems such as decline in sales volume, market share, and inability to achieve marketing and corporate goals (Ibidunni et al., 2014; Aldaas et al., 2019). The Jordanian government recognized the importance of SMEs for many reasons such as reduction in unemployment rate, jobs creation, and development of rural areas, and thus, the government can develop regulations to reduce challenges and problems which are encountered by Jordanian SMEs. Therefore, the current study investigates the role of product innovation and flexibility in increasing performance especially market share in Jordanian manufacturing SMEs. The paper structure will be as follows; the study outlines are highlighted. Critical review of relevant literature is conducted through previous studies. The methodology is developed using quantitative analysis. The study findings, implication, and recommendations are presented. Limitations are highlighted. As a result, this study has conducted to answer the following question:

Q1. What is the role of product innovation and flexibility in increasing market share in Jordanian manufacturing SMEs?

Therefore, the study aims and objectives is to identify the current status of product innovation and flexibility from management perspectives in Jordanian manufacturing SMEs, measuring the effect of product innovation on gaining market share in Jordanian manufacturing SMEs, measuring the effect of product flexibility on gaining market share in Jordanian manufacturing SMEs, and provide recommendations and practical implications to SMEs managers.

2. Literature review

2.1 SMEs in Jordan as a research context

Al-Weshah et al. (2013) stated that smaller firms are more entrepreneurial, which enhances adoption and improves the learning process. In Jordan like other developing countries, SMEs often have limited resources, leaving them at a relative disadvantage compared with a higher perceived risk than larger companies. Al-Hyari et al. (2012) stated that Jordanian manufacturing SMEs are forced to go beyond the Jordan local market to survive. More and more companies are facing challenges of globalization with the accompanying open borders

SMEs make an extremely important contribution to an economy, especially to the rapid growth in developing countries (Al-Weshah, 2019a). Like other countries, the private sector in Jordan is consisted of large, medium and small firms that employ 628,554 employees as total size of employees in Jordanian private sector. Only 31% of employees work in large firms and the rest employees work in SMEs. 82% of SMEs employees are male and only 18% are female. The density of SMEs is lower than other low-income countries (JHDR 2011, P15, and P20). The Jordanian economy depends entirely on small and medium-sized companies to drive its growth. About 98% of businesses in Jordan are considered as SME's, 67% of Jordanian SMEs have less than (19) employees. SMEs employ about 60% of the total workforce in Jordan. SMEs contribution to Jordanian GDP is 50%, and manufacturing enterprises form 14% of total Jordanian SMEs (Share, 2014).

The definition and classification of SMEs varies from one governmental agency to another, for example, according to Jordan Human development report in 2019 (JHDR, 2019), Small businesses that employ (1-19) employees are further classified into two classes, (1-4, and 5-19). Whereas, medium businesses that employ (20-99) employees are further classified into two classes, (20-49, 50-99). The Jordanian Ministry of Industry and Trade classifies SME's based on the number of employees as in the following "Table 1" (MIT, 2019).

Table 1. Classification of SMEs according to Ministry of industry and Trade in Jordan

Classification	No of employees
Micro	1-9
Small	10-49
Medium	50-249
Large	250 +

There are many definitions by UNIDO and the Arab labour associations according to the (JHDR, 2019), where micro enterprises are ranged from 1-4 employees, number of employees in small enterprises are ranged from 5-19 employees, and medium enterprises are ranged from 20-100 employees. Najjar (2004) also classified MSMEs as small enterprises that employ 5-19 employees, and medium enterprises that employ 20-100 employees. According to the Jordanian SMEs Association, SMEs are considered as one classification, they consider that SMEs employ between 10-249 employees. Therefore, in the current study, SMEs classification will be based on number of employees, the most useful definition of SMEs is that enterprises of 5-19 employees are small and enterprises of 20-100 employees are medium.

2.2 Innovation and flexibility in manufacturing strategy

Innovation is one of major competitive priorities that can be considered by manufacturing businesses in to maintain and increase their market share and extend or create long products life cycles. Boyer, et al. (2005)

confirmed that a competitive advantage can be created by low cost products. By using this approach, the industrialized countries can make remarkable progress in their competitive capabilities through employing different types of innovations. Butt (2009) concluded that the major dimensions of manufacturing strategy are time efficiency and innovation processes.

Valery (1999) confirmed that innovation is a core issue in this economic era. Local governments and businesses adopt innovation when they are trying to flourish the economic environment. Innovation can provide new technologies for different industries. Dobni (2010) stated that the innovation capacity of manufacturing firms can motivate businesses growth and profitability. More studies were conducted to investigate the high importance of innovation such as (Zhao et al., 2002; Zakaria et al., 2012) who stated that many scholars propose different dimensions to the four basic dimensions of innovation (cost, quality, delivery and flexibility).

Previous studies stated that flexibility is a strategic driver of manufacturing, hence, flexibility is classified into different categories such as product flexibility, new product flexibility, market flexibility, machine flexibility, labor flexibility, process flexibility, volume flexibility, and expansion flexibility (Narasimhan and Das, 2000). Product flexibility can be considered as a competitive weapon to adapt businesses with flux markets, dynamic environments, and fluctuating product life cycles (Sethi and Sethi, 1990). The goal of flexibility is to deal with uncertain conditions to respond effectively to changing environments. New product flexibility (NPF) is an essential and strategic tool in manufacturing flexibility (Narasimhan and Das, 2000). Awwad (2007) recommended that product flexibility is the fundamental link between marketing strategies and manufacturing strategies

2.3 Product innovation

Innovation is the ability of a business to develop or improve its products, services, and different manufacturing processes. It is also the continuous capability to develop business products that match changes in customer demand (Naqshbandi and Idris, 2012; Abuhashesh et al., 2019a, b). Thompson (1965) defined innovation as the generation, screening, acceptance, and implementation of new ideas, products, services, and processes. Innovation is the core issue in the late 20th Century; businesses consider innovation as the key tool to increase profits, growth, and market share (Al-Nsour and Al-Weshah, 2011). Governments can automatically reach for innovation level when they are trying to improve the economic conditions that lead to economic welfare (Valery, 1999, (Al-Weshah, 2019b).

Zhao et al. (2002) concluded that product innovation is not only limited to physical products but also included their applications on intellectual products. Traditionally, innovation is used to create new production processes, however, innovation can be considered as a high priority in developing new markets for the business products. Innovation is defined by many scholars as process or product development for a business. Specifically, it is introducing innovative products and new processes to adapt with new environments (Russell and Millar, 2014; Hassan et al., 2013).

Innovation is considered as issue to help firms in identifying their problems, responding to unexpected conditions, creating potential solutions for problems, and developing new ways to manage different businesses using experience, skills, motivation and the organizational knowledge. These issues are converted into production of an innovative product or service (Miettinen et al. 2009). Wierdsma (2004) stated that innovation is the process of new outcome development by adopting new ways and tools of product and service development. Crossan and Apaydin (2010) concluded that innovation refers to create or accept, adapt, and utilize value-added novelty in service and manufacturing areas such as re-generation products, adopting new ways of product development, and offering new services. Al-Weshah (2018) also stated that e-marketing practices can be used to enhance product innovation and development.

According to the Organisation for Economic Co-operation and Development (OECD, 2019), there are four classifications of innovation namely, organizational innovation, marketing innovation, process innovation, and product innovation. More specifically, organizational innovation is improving new business practices by an organization, in addition to updating work environment, and building external interfaces and relations. Marketing innovation is adopting new improvements in different issues such as product promotion, packaging, and new pricing plans. Process innovation is executing an improved process that can be used to support production and efficiency. Finally, product innovation is producing or introducing new products and services that are practically improved over their predecessors.

Brunswicker and Ehrenmann (2013), stated that innovation in SMEs is not well established concept, where innovation is limited to internal environment of organization such organizational structure Brunswicker and Ehrenmann (2013) addressed that the concept of open innovation includes inbound and outbound innovation; inbound innovation is where ideas and thoughts are coming from external environment to an organizational environment, while outbound innovation is where new technologies and creative ideas are available for organizations in an industry. Moreover, Nybakk and Jenssen (2012) examined the innovation strategy and its effect on financial performance in Norwegian wooden manufacturing businesses. They concluded that innovation has a positive effect on financial performance of manufacturing businesses. Innovation was ranked as first dimension in manufacturing strategy comparing with other dimensions in manufacturing firms (Zhao et al., 2002). Cheng and Wang (2011) investigated the relationship between strategies of governmental regulations and manufacturing performance in SMEs, they confirmed that innovation in SMEs has a positive effect on both financial and non-financial performance.

Thrassou et al. (2012) suggested that value is the core issue in the innovation; innovation can meet potential changes in consumer behavior, it can also enhance the strategic orientation of marketing. Accordingly, practices of new product development (NPD) can be developed to meet potential changes that are related to the product life cycle stages. Al-Weshah (2013) also considered that innovation in the market is one of the major aspects of new product development (NPD). Hassan et al. (2013) investigated the effect of different categories of innovation (product, process, marketing, and organizational innovation) on businesses performance in 250 manufacturing companies in Pakistan. They concluded that all innovation types have positive impact on firm performance. Leitner (2016) concluded that product innovation in SMEs leads to an important development in different industries which were also supported by business press, consultancy firms, and governmental innovation policies.

In this study, innovation is defined in product and process as producing new product, reducing new product development time, improving production processes, and increasing the breadth of new products. Innovation is measured in the study by enterprise continuous ability to introduce new products and services, time reduction of product improvement, technology utilization, and a firm ability to maintain the process of product development. Based on the previous literature, the following hypothesis was developed:

H01: There is no significant effect of product innovation on market share in Jordanian manufacturing SMEs.

2.4 Flexibility of manufacturing products

Awwad et al. (2013) stated that is a construct with different dimensions and it can be considered as a competitive tool in any manufacturing or service business, especially in managing demand to meet changes in customer needs, preferences, and expectations. Naqshbandi and Idris (2012) stated that flexibility can be used as an approach of product adaptation to customer needs and requirements to absorb changes in global and local business environments. Generally, product flexibility has two classifications; time flexibility and customization flexibility. Time flexibility represents how to respond quickly to changes in market through the offering new products and services, whereas, customization flexibility is how to produce a product or serve a customer according to changes in customer needs.

Previous studies stated that flexibility is a strategic driver of manufacturing and it was classified into different categories such as product flexibility, new product flexibility, market flexibility, machine flexibility, labor flexibility, process flexibility, expansion flexibility, and volume flexibility (Sethi and Sethi, 1990; Narasimhan and Das, 2000). Khademolomoom and Emeagwali (2015) also focused on the dimensions that are most frequently used in approaching flexibility. The study divided flexibility into five critical and fundamental types, namely, new product flexibility (NPF), sourcing flexibility (SOF), product flexibility (PRF), delivery flexibility (DLF), and information systems flexibility (ISF).

Awwad et al. (2013) classified flexibility into three categories; namely, necessary flexibility, sufficient flexibility, and competitive flexibility. The necessary flexibility includes (machine flexibility, product flexibility, labour flexibility, materials handling flexibility, routing flexibility, volume flexibility); the sufficient flexibility includes (process flexibility, operational flexibility, programme flexibility, materials flexibility); and the competitive flexibility includes (production flexibility, expansion flexibility, market flexibility. Tracey et al. (1999**)** investigated the flexibility of product line breadth in American manufacturing firms; they confirmed that flexibility of product line breadth has higher level of performance, in terms of customers and market performance. Awwad et al. (2013) concluded that flexibility provides a firm with the ability to handle variations in many issues such as establishing customer delivery schedule, introducing new parts or new products quickly, adjusting capacity rapidly, and customizing products to handle changes in the product mix. Product flexibility was adopted to create and develop the production facility than can be used for flexible products (Sethi and Sethi, 1990); product flexibility can be considered as a competitive weapon to adapt businesses with flux markets, dynamic environments, and fluctuating product life cycles (Sethi and Sethi, 1990). The goal of flexibility is to deal with uncertain conditions to respond effectively to changing environments. New product flexibility (NPF) is an essential and strategic tool in manufacturing flexibility (Narasimhan and Das, 2000).

Product flexibility plays a major role in linking operations strategy to marketing strategy that provides an organization with the ability to introduce new products, adjust capacity rapidly, and customize products to customer needs (Awwad, 2007). Product flexibility is employed to introduce creative products and to create awareness of customers in target markets. More specifically, product flexibility is the ability of business to deal with non-standard orders that meet special customer requirements. It may used to produce varieties of products that are characterized by different features such as options, sizes, or colors (Vickery and Calantone, 1999). Product flexibility enables a business to meet the market needs through developing newly designed products in quick ways (Kara et al., 2002). Kara et al. (2002) argued that new product flexibility provides a business with the ability to develop new products in quick ways. Awwad (2007) confirmed that new product flexibility can be used to meet customer needs and expectations.

In this study, flexibility is defined as the ability of a manufacturing business to manage resources that respond to variation in contractual needs, change in design, change in volumes, and change in plans. Flexibility is measured in the study by the business ability to reduce setup time of production lines, develop production lines, meet changes in demand variations, produce wide range of products, and respond to time changes of customer demand. Based on the previous literature, the following hypothesis was developed:

H02: There is no significant effect of product flexibility on market share in Jordanian manufacturing SMEs.

2.5 Market share: concepts and measurements

Market share was defined initially by Cooper and Nakanishi (1998) as share of the market commanded by a business product (or a brand). Researchers also argued that the concept of market share is not defined accurately; hence, an established definition of market share is needed for further studies (Al-Weshah, 2011). Market share can be considered as group of consumers or business users who are potential and current buyers of a firm's product. Therefore, market share is defined by (Cooper and Nakanishi, 1998) as shares of potential consumers. Most studies considered market share as a dimension to measure business performance such as Anderson (1994) and Al-Weshah et al. (2011) who defined market share as the percentage of the total market that is dominated by firm's product or variety of products, or the number of customers or percentage of a service offered to customers.

Al-Weshah et al. (2011) stated that the market share term has different perspectives and there is no one definition for the term of market share. Previous studies use market share as an indicator for "sales volume" and they consider that the two terms are synonymous. However, many studies stated that market share is represented as the ratio of a firm's sales to the total sales of its industry. Haider (2009) proposed that there are fundamental guidelines for a firm to increase its market share such as customer relationships, promotional schemes, product differentiation, focused advertising, and post-sale services. Al-Weshah (2017) stated that customer relationship is an important to maintain current customers and capture new customers, hence, increasing market share.

Moghaddam and Foroughi (2012) examined the effect of marketing strategy on firm performance, specifically market share in industrial firms in Iran. They confirmed that marketing strategy elements and marketing mix elements can increase market share. Moreover, there are many sub-elements in the strategy can be used to increase market share such as post-sale services, pricing, period of payment, offers of discounts, practicing direct marketing, educated sale staff, and on-time delivery Vlachvei and Oustapassidis (1997) identified the determinants of market share in the food industry.. They stated that market share determinants were intensive advertising, number of brand names, industry and market size, and economics of scale. Minov (2014) investigated competitive levels in the telecommunication sector in Austria. The researcher confirmed that enterprise size and customer loyalty of brands are the main parameters and indicators for market share. Benkovskis and Wörz (2013) identified the critical factors of price and non-price that affect change in market share variations among the seven major advanced economics (G7). The study confirmed that non-price factors of export performance have a significant effect on market share variations.

3. Research methodology

This section indicates the methodology applied in the study in hand. It consists of research model, research hypotheses besides, data collection tools, population and sampling.

3.1 Research approach

The elements of this research are established based on preceding literature review either theoretically or empirically. The quantitative approach generally and hypotheses testing method particularly are employed in the current study, more specifically, frequencies analysis, correlation analysis, simple regression, and multiple regression analysis are considered using SPSS (Statistical Packages for Social Sciences).

3.2 Population and sampling

The targeted population of this study consisted of Jordanian manufacturing enterprises in the King Abdullah II Industrial Estate. The Industrial city includes 472 manufacturing enterprises. Self- administered questionnaire was used as the most appropriate method of data collection. After developing the final copy of the questionnaire, 270 questionnaires were distributed personally to CEOs and managers of SMEs in the King Abdullah II Industrial City. 236 questionnaires are returned and collected by hand from these enterprises after one week with response rate is %87. A probability sample, more specifically, stratified random sample, representing both small and medium enterprises- is employed by the current study.

4. Data analysis and results

To examine the impact of Product Innovation and Flexibility as Competitive Priorities in Gaining Market Share, in which these variables have been measured using five-point Likert scale that varies between strongly disagree =1 and strongly agree =5. Also, reliability and validity analyses were conducted; descriptive analysis was used to describe the characteristic of the sample and the respondents to the questionnaires along with the independent and dependent variables. In addition, Statistical analysis such as frequencies analysis, simple regression, multiple regression, and ANOVA are calculated using SPSS to test the study hypotheses.

4.1 Validity and reliability

Validity and reliability are two key measures that are used to determine the quality and usefulness of the primary data. Validity is about accuracy and whether the instrument is useful, while reliability is about precision; it is used to check the consistency and stability of the questionnaire. Indeed, the researchers depend on scales and items that were previously developed and used by other researchers with similar interest. In addition, a draft of the questionnaire was formulated, for validity purposes, the questionnaire is pre-tested by many academic professors and experts from manufacturing SMEs to ensure that each item is effective and avoid the ambiguity and complexity in the phrasing of questions. To measure the instrument reliability, the Coefficient of Cronbach's Alpha is considered for all study variables as shown in "**Table 2**". Cronbach's Alpha for all variables are above 70% and accepted in these types of studies.

Table 2. Reliability coefficients of the Questionnaire

Variable of the study	Cronbach's Alpha Coefficient	No of Questions
Product innovation	0.814	5
Product flexibility	0.783	5
Market share	0.810	8
All Variables	0.771	18

The collected data represent 115 small enterprises and 121 medium enterprises. The participated enterprises in this study are classified into sub-sectors as in **table 3**.

Table 3. SMEs classification according to number of employees for selected enterprises in the study

Number of Employees	Frequency	Percentage
5 employees - less than 20 employees	115	49.13
20 employees - less than 100 Employees	121	50.87

Total	236	100

As shown in the "**Table 3**", the number of participated small enterprises in the study is almost equal to the number of medium enterprises.

As shown in the "**Table 4**", the plastics industries have the largest share of enterprises that represent (19.06%) of selected enterprises. Whereas, the lowest share of enterprises are medical materials industries that represent (5.50%) of the selected enterprises.

Table 4. Industrial sub-sectors for the selected enterprises from the King Abdullah II Industrial Estate

Industrial Sector	Frequency	Percentage
Chemical industries	38	16.10
Food and agricultural industries	34	14.41
Papers, cartoons, and packaging	38	16.10
Plastic industries	45	19.06
Medical material industries	13	5.50
Furniture industries	18	7.62
Constructions industries	14	5.93
Leather and tissues materials	17	7.20
Electrical and engineering industries	19	8.05
Total	236	100

4.2 Descriptive analysis

This section provides some descriptive statistics such as mean, standard deviation, and importance degree for each variable in the study. To describe the responses and thus the attitude of the respondents toward each question in the survey, the mean and standard deviation were estimated. While the mean shows the central tendency of the data, the standard deviation measures the dispersion which offers an index of the spread or variability in the data (Sekaran and Bougie, 2016)

4.2.1 Product innovation statistics

To show the current of product innovation as independent variable in Jordanian manufacturing SMEs, some statistics are calculated using SPSS such as mean of factors, standard deviations, and ranking importance of each factor.

As shown in the "**Table 5**", it is apparent that the overall mean of innovation factors is ranked as high importance. Moreover, "continues product development" statement is ranked as the highest mean statement with an average of (4.131) and SD (0.873). On the other hand, "Updated technology adoption" statement is ranked as the lowest mean statement with an average of (3.901) and SD (0.891).

Table 5. Innovation statistics, means and standard deviations

Innovation Factors	Mean	Std. Dev	Statement Rank	Importance Degree
Continuous product development.	4.131	0.873	1	High
Time Reduction of product development	4.120	0.899	2	High
Updated technology adoption	3.901	0.891	5	High
Product diversity	4.113	0.726	3	High
New product collections	4.093	0.754	4	High

4.2.2 Flexibility of products statistics

To show the current of product flexibility as independent variable in Jordanian manufacturing SMEs, some statistics are calculated using SPSS such as mean of factors, standard deviations, and ranking importance of each factor.

As seen in the "**Table 6**", the relative importance of all flexibility factors is ranked as high importance. the statement 5, "Ability to meet changes in delivery times " is the highest mean statement with an average of (4.218) and SD (0.801), while the statement "Reduction in procurement times" is ranked as the lowest mean statement with an average of (3.722) and SD (0.819) , but still high in importance.

Table 6. Flexibility factors means and standard deviations

Flexibility Factors	Means	Std. Dev	Statement Rank	Importance Degree
Reduction in Delivery times	3.994	0.814	2	High
Reduction in procurement times.	3.722	0.819	5	High
Ability to meet changes in demand size	3.815	0.782	4	High
Ability to develop diversified product mix.	3.898	0.824	3	High
Ability to meet changes in delivery times	4.218	0.801	1	High

4.2.3 Market share statistics

To show the current status of the market share as dependent variable in Jordanian manufacturing SMEs, some statistics are calculated using SPSS such as mean, standard deviations, and ranking importance of each factor.

As shown in the "**Table 7**", the degree of importance of all market share statements are high. Specifically, "Image and reputation of brands affect market share" is ranked as the highest statement with an average of (4.213) and standard deviation of (0.820), while "Number of firms brands reflect market share" is ranked as the lowest statement with a mean of (3.812) and standard deviation of (0.741) with high level of importance.

Table 7. Market Share factors means, standard deviations

Market Share	Mean	Std. Dev	Statement Rank	Importance Degree
Promotional efforts enhance market Share.	3.901	0.792	5	High
Number of firms' brands reflect market share.	3.812	0.741	8	High
Firm size affects market share	3.986	0.793	4	High
Customer loyalty can increase market share	4.151	0.811	3	High
Image and reputation of brands affect market share.	4.213	0.820	1	High
Varieties of product lines can increase market share.	4.211	0.753	2	High
Diversity of brands can increase market share.	3.872	0.824	7	High
Geographic coverage of products can increase market share.	3.881	0.751	6	High

4.3 Hypotheses testing results

This part shows the hypotheses testing for two main hypotheses based on simple regression, and ANOVA using SPSS (Statistical Package for Social Sciences). The current study includes the following hypotheses:

4.3.1 The effect of competitive priorities on market share

To measure the effect of competitive priorities with its dimensions (product innovation and flexibility) product on market shares in Jordanian manufacturing SMEs. Using multiple regression model, the findings are shown in **"Table 8"**.

Table 8. Multiple regression for competitive priorities

Competitive priorities	Beta	T	Sig
Product innovation	0.152	2.751	0.014
Product Flexibility	0.173	2.842	0.011
R^2	0.153		
F	9.329		
Sig	0.000		

Table 9. The effect of product innovation on market share

Dependent variable	Model Summery		ANOVA			Coefficients				
	R	r^2	F	Df	Sig F*	Independent variable	B	Std Dev	T calculated	Sig t*
Market share	0.235	0.055	12.397	1	0.001	Product innovation	0.162	0.053	3.521	0.001

* Statistical effect at a significant level (α ≤ 0.5)

According to the "**Table 8**", the results of multiple regression show that there is a significant effect of competitive priorities with its dimensions (product innovation and flexibility) product on market share in Jordanian manufacturing SMEs., since (F= 9.329, P <0.05), therefore, the null hypothesis is rejected and the alternative hypothesis is accepted. The results show that (R^2= 0153) which indicate that competitive priorities explain 15.3% of the variance in the market share as a dependent variable.

4.3.2 The effect of product innovation on market share

To test the first hypothesis, simple regression method and ANOVA analysis and are used; the results are shown in "**Table 9**".

As shown in the **"Table 9"**, value of B is 0.162 which indicates to the maker share regardless of the product innovation. The results show that the R value is 0.235, which indicates that there is a positive association between the product innovation and the market share in manufacturing SMEs. Moreover, R^2 value is 0.055, which refers that the explained ratio of product innovation is only 5.5% in variance of market share in SMEs. T value is 3.521 with significant level (α ≤ 0.5) and F value is12.397 at the significant level is 0.001., therefore it can be confirmed that the null hypothesis can be rejected and the alternative hypothesis is accepted. As shown by the results, the weak effect of product innovation on increasing market share can be justified that the product innovation is limited in Jordanian SMEs. Limited innovation practices refer to lack of employees' skills, shortages of financial resources, lack of research and development, and poor marketing activities to communicate with customers in the manufacturing Estates.

The study results are supported by Kumar et al. (2010) study in Canadian product manufacturing firms, they concluded that flexibility is very important in the beginning of the product life cycle. Dangayach and Deshmukh (2001) also stated that due lack of relevant resources for research and development; SMEs do not have enough innovation practices. Al-Weshah et al. (2011) in their study for using e-networks in gaining market share, they confirmed that there are many barriers for increasing SMEs market share such as lack of employee's skills in terms of English language skills and marketing skills. Ibidunni et al. (2014) also stated that some SMEs do not invest many resources on the utilization of modern technologies, as this leads to decline in products design and deployment.

Table 10. The effect of product flexibility on market share

Dependent variable	Model Summery		ANOVA			Coefficients				
	R	r^2	F	Df	Sig F*	Independent variable	B	Std Dev	T	Sig t*
Market share	0.261	0.068	21.261	1	0.0000	Product flexibility	0.245	0.055	4.611	0.000

* Statistical effect at significant level (α ≤ 0.5)

4.3.3 The effect of product flexibility on market share

To test the second hypothesis, the simple regression method and ANOVA analysis are used; the results are shown in "**Table 10**".

As shown in the "**Table 10**", value of B is 0.245 which indicates to the maker share regardless of the product flexibility. The results show that the R value is 0.261, which indicates that there is a positive association between the product flexibility and the market share in manufacturing SMEs. Moreover, R^2 value is 0.068, which refers that the explained ratio of product flexibility is only 6.8% in variance of market share in SMEs. T value is 4.611 with significant level ($\alpha \leq 0.5$) and F value is 21.261 at the significant level is 0.000. Therefore, the results show that null hypothesis is rejected and the alternative hypothesis is accepted.

As shown by the results, the weak effect of product flexibility on increasing market share can be justified that the product flexibility is still at embryonic stages in Jordanian SMEs. The weak effect of flexibility refers to lack of design' skills, shortages, poor market segmentation, lack of research and development, and poor marketing activities and customer relationship management (CRM) to keep on touch with customers and get their feedback about proposed products in the manufacturing areas.

The study results are supported by many studies such as Amoako-Gyampah and Acquaah, (2008) and Sakhter and Pounder (2008) who stated that flexibility is a product manufacturing strategy that can be used by manufacturing firms to shape customer needs and preferences in the market. The results are also supported by Zhang et al. (2003) who stated that many issues such as product customization, pressures of globalization, and technological innovation can be adopted to support radical changes in customer expectations, thus, market share. Ibidunni et al. (2014) also stated that any SME survival is not guaranteed without assessing consumption patterns that adapt them with the dynamism of the environment.

5. Discussion and conclusions

This study investigates the role of product innovation and flexibility in increasing market share in the Jordanian manufacturing SMEs. Also, the study focuses on considering different competitive priorities of their manufacturing activities that support business units to become more competitive to increase market share. Moreover, Product innovation can be used to gain the market share over competitors, and to improve a competitive position of the business. Product innovation is one of the essential strategies of growth that usually adopted by companies to serve new market segments, to gain market share, and to improve competitive position of the business. Product innovation can satisfy the dynamic changes in customers' taste and performance. Thus, product innovation can increase sales volume of SMEs and face tremendous competition. In addition, innovation represents solutions to achieve many issues for businesses such as low cost and high quality, hence, innovation is a business strategy that can sustain and grow businesses.

Furthermore, the study focuses on flexibility which is the products adaptation to customer needs and requirements of different changes. Flexibility also is the business ability to adapt to changing and dynamic business environment globally and locally in terms of time flexibility and customization flexibility. The study results show a positive association between the product innovation and the market share in manufacturing SMEs. Also, the study indicates that there is a positive association between the product flexibility and the market share in manufacturing SMEs. The results are also supported by Zhang et al. (2003) who stated that many issues such as product customization, pressures of globalization, and technological innovation can be adopted to support radical changes in customer expectations, thus, market share.

The study results emphasis that lack of employees' skills, shortages of financial resources, lack of research and development, and poor marketing activities to communicate with customers can limit innovation practices and leads to decline in products design and deployment. Furthermore, the study stress out that lack of design skills, shortages, poor market segmentation, lack of research and development, and poor marketing activities and customer relationship management (CRM) to keep on touch with customers and get their feedback about proposed products in the manufacturing areas can lead to weak effect of product flexibility on increasing market share. The study results are supported by many studies such as Amoako-Gyampah and Acquaah, (2008) and Sakhter and Pounder (2008) who stated that flexibility is a product manufacturing strategy that can be used by manufacturing firms to shape customer needs and preferences in the market.

5.1 Practical implications

Based on the study results, many recommendations can be proposed by the study. The manufacturing sector has to focus on all manufacturing strategies dimensions. However, the manufacturing sector must be more concerned with different types of innovation especially product innovation, which is presently lower than needed to benefit from markets available for Jordanian products. Product innovation can provide SMEs with more leverage than is needed in competition with other international products. Flexibility of products has vital importance, but without innovation, SMEs will be one step behind other sectors. In the other hand, western SMEs have already reduced international competition by adopting innovation strategies. Consequently, Jordanian manufacturing SMEs should establish an innovation fund of Jordanian SMEs to confirm the edge needed for competition. Moreover, flexibility of products is one of major competitive priorities that enable a business to deal with competitive moves. Product flexibility enhances the business contribution to develop new products and take the strategic decisions of entry to or exit from the markets (Abuhashesh et al., 2019c). NPF can be used by SMEs to enhance their organizational performance through rapid entry to new markets.

To activate the role of product innovation and flexibility, management support and commitment is needed here. Moreover, market research is a driver of new product introductions to adapt our SMEs products with changing environment. Doing research on dissatisfied customers to assess their needs is priority for marketing SMEs. SMEs have to evaluate their current products as a key for such types of incremental product innovation. Benchmarking strategies and learning processes from experience of other industries can be considered by managers especially in product design in to extend product life cycle. Product innovation and flexibility must be planned and implemented by Jordanian manufacturing SMEs through developing operation and marketing strategies to respond effectively and efficiently to shortened product life cycles.

SMEs managers have to take manufacturing advantages that stem from business capabilities and strategic aware and adaptation. These capabilities enable SMEs to adopt a competitive strategy in terms of product innovation and flexibility. The interaction between SEMs staff and customers is highly important to get suggestions for the product development. The management has to focus on communication capabilities within the firm to formulate a competitive strategy which are related product innovation and flexibility.

5.2 Theoretical implication

The study also orients the researchers in the manufacturing domain to use this study and its conceptual model to assess the effect of product innovation and product flexibility as competitive priorities on increasing market share in Jordanian manufacturing SMEs. It also suggests expanding this study and evaluating the effect of product innovation and product flexibility in different places and different industrial sectors. Future research could also adopt the instruments of this study and measure the effect of product innovation and product flexibility to increase market share. In addition, researchers could benefit from the results of this study and provide recommendations to the industrial decision-makers and manufacture managers regarding the best ways to expand their market share, increase customers' satisfaction, and to improve a competitive position of the business.

5.3 Recommendations and limitations for further research

The study has some limitations. The current study has been restricted to Jordanian manufacturing SMEs and more specifically in King Abdullah II Industrial Estate. The study considers only product innovation and product flexibility as competitive priorities. The current study adopts quantitative and hypothesis testing approach. In the light of study limitations, some recommendations can be proposed for future studies. In future studies, extended research is needed to cover all industrial cities in the north, middle and south of Jordan. Also, further research is needed with regards to several countries around the world since this would help to advance understanding of the research topic from different nationwide origins in different contexts. Another limitation is that the proposed model is based on the cross-sectional data from Jordan; therefore, longitudinal investigations are preferred for better implications of the research topic. Methodologically, future studies can employ qualitative studies to investigate different aspects of manufacturing SMEs with different roles. Future studies can also investigate the impact of innovation and flexibility on product life cycle and its extension. Future studies can investigate different competitive priorities such as cost, quality, delivery, talent, manager, and market strategy.

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'Breaking the Silos' of Innovation Methods

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Abstract

After having dealt with silos amongst people, we have found ways of creating silos amongst innovation methods. Each method claims to be 'the master' method for innovation and each new one claims to be superior to the previous ones. Many organisations that leverage multiple methods tend to do so by applying each one in specific stages of a project. While working with multiple methods in different roles of innovation, the author realises that many methods say the same thing in different words and have something unique to offer across different stages of an innovation project. With this realisation, the author has led a team of innovation managers to evolve a harmonised method which can be contextualised in diverse set of contexts. The attempt of this paper / article is to share an overview of the harmonised method, some of its key outcomes and ways in which the method became a pivot for institutionalising innovation culture across an already innovative Group of companies which is a multi-billion-dollar Indian MNC that operates in about 17 sectors in about 100 countries. For confidentiality, only sanitized data are presented in this paper.

Keywords: inspiration, interplay, mindset, systematic.

1. Introduction

There are multiple methods for innovation available across the world and then there are many 'derived' versions of some of these methods. A list of methods engaged with for the purpose of this work are listed in SECTION 2.0 LIST OF METHODS ENGAGED WITH of this paper along with the related references which may be accessed for further information.

Although, each method & its respective versions have unique strength in certain aspects of innovation, many methods say the same thing in different words.

This has been found to often put average innovators in a dilemma of what, when & how to use. As a result, they often end up using each one separately and thereby limiting their abilities to come up with more innovations consistently. On the other hand, top innovators, do it all intuitively without really worrying about the method from which they have achieved it.

In the context, where innovation needs to be institutionalised, the need of a common language is essential. With this intent, the Innovation Team at Automotive & Farm sector of Mahindra & Mahindra Limited, embarked on a journey to harmonise all the methods that were found to be successfully deployed in the organisation while keep it open to include newer methods as and when these were found to be relevant.

2. List of methods engaged with

Apart from the engagements mentioned below, the understanding evolved is also based on innumerous interactions that the author has had with people at events, conference, meetings etc. While doing so, the author has also come across many other methods / approaches. A list of specific methods and their sources referred for this work are as follows.

(1) Design Thinking (DT) by way of referring to the work of Brown Tim (2009), DesignThinking section of Ideo's website, Ideo University website and its many variants through interactions
(2) Orbit-shifting Innovation (OSI) by way of referring to the work of Munshi (2009), Narang et all (2013) and working with Erehwon Innovation Consulting Pvt Ltd (2008 onwards)
(3) TRIZ by way of referring to TRIZ40 (2016-17), Systematic Innovation (2014-2020)
(4) Systematic Inventive Thinking (SIT) by way of referring to the work of Boyd et all (2013) and the team at SIT during 2017-18

(5) Business Model Innovation (BMI) by referring to the work of Osterwalder et all (2010a), Osterwalder et all (2014b), and interactions with the team from Strategyzer (2017-18)
(6) BMGI India by partnering with them in 2017-18.
(7) Biomimicry 3.8 (B3.8) partnered with their team from 2017 to 2019
(8) Lateral Thinking (LT) through partnership with DeBono Edward in 2009
(9) Business Experimentation by referring to the work of Thomke et all (2014)
(10) Open Innovation / Crowd Sourcing by way of partnership with Innocentive from 2013 to 2015 and interactions with Idea Connection in 2017 but continuing to refer to their content from 2015 till date.

More details about each source is also mentioned in SECTION 7. References.

3. The approach

It has often been said that innovation is all about the mind & mindset, the Mahindra INnovation methoD evolved with an acronym MIND™. It entails a systematic approach to drive innovation projects right from identification to implementation stages.

MIND™ is not a rigid process but a flexible & customisable framework of guiding principles & templates. In true sense, it is an approach and the path to navigate it will depend upon the context. This path can be complex because of the iterative nature of innovation. However, to keep it simple it has been depicted in a sequential framework & called a method. The names of its stages also leveraged the same acronym viz. **M**ap, **I**deate, **N**urture & **D**eploy. To highlight the fact that this method goes deeper than most other methods, depth was highlighted in three layers which also leveraged the same acronym viz. recognise & manage **M**indset, **IN**spire the mind to generate new possibilities and **D**evelop the outcome of each stage. Thus, forming a 'framework' which is all about **M-I-N-D**.

The stages and the layers are also not necessarily sequential and there is a lot back-and-forth (circularity / non-linearity) in the flow of a journey. Again, to keep it simple, these have been depicted as sequential. "**Fig. 1**" shows the pictorial representation of the MIND™ framework.

The MIND™ integrates the power of multiple methods. At the core of it are the methods like Orbit-shifting innovation (OSI), Systematic Innovation version of TRIZ (SI/TRIZ) & Biomimicry (B3.8). Other methods like Design Thinking (DT), Business Model Innovation (BMI), Systematic Inventive Thinking (SIT), Open Innovation (OI) have been integrated at relevant points in the method. MIND™ is also open & flexible enough to integrate more methods / approaches that the organisation would find relevant in future.

Although any Open Innovation platforms have not been leveraged so far while deploying MIND™, the concept was leveraged by inviting members of other businesses / sectors to help the core project team ideate further or for supporting the prototype development work.

MIND™ encourages users to use all the constituent methods together rather than leveraging each only in the stage where it is stronger. The way MIND™ leverages different methods at each of the stages is mentioned here-below.

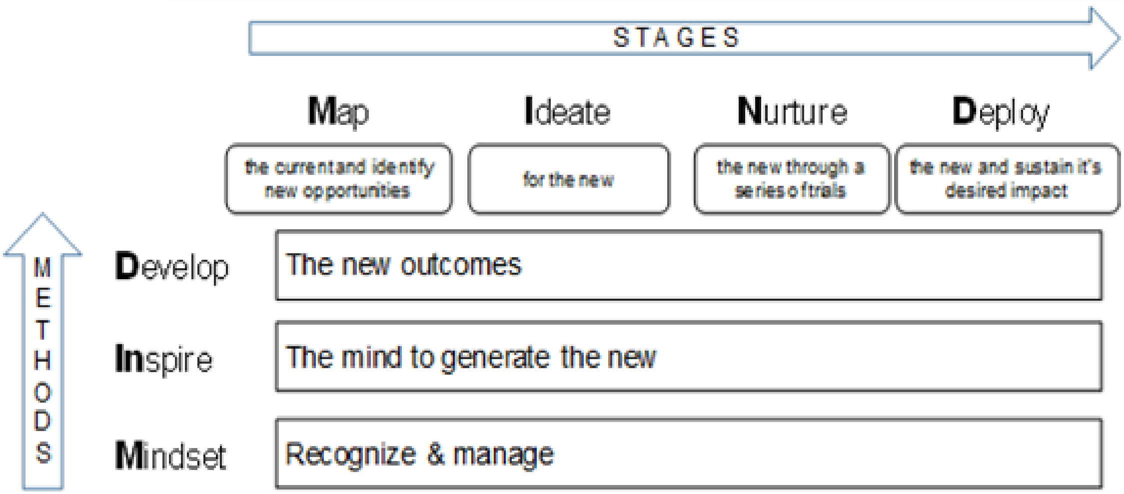

Fig. 1 MIND™ framework.

3.1 Map

While most methods have a well-documented set of trigger questions for mapping the current and the desired end state, OSI is the strongest in this area with its techniques like Mental-Model-Mapping, Orbit-shift-Insighting, Breaking-Through-Gravity and Co-creating-an-Orbit-shift-Aspiration.

These techniques inspire the team to co-own a goal that seems impossible from their current ways of thinking. The Mental Model Maps bring out the current ways of thinking. With this the entire team can visualise the 'box' in which they are operating.

While TRIZ/SI provide triggers like the Ideal Final Result & Identify Contradictions and Biomimicry provides triggers based on the documented examples of some of the nature's ways of doing things.

Open Innovation / Crowd sourcing platforms like Innocentive have a separate offering for ideation only and can be leveraged for a high volume of ideas. The only challenge is for the project team to review & prioritise these ideas. OSI's Mental Model Mapping techniques are helpful here too.

Orbit-shift-insighting enables uncovering of latent / unstated needs of the stakeholders. Apart from listening to the 'voice-of-the-person, it is also geared for capturing the emotions / 'silence-of-the-person'.

OSI has provision to take triggers from all methods as inputs into evolving a comprehensive Mental Model Map. The Breaking-Through-Gravity techniques enables the teams to set an aspiration that is 'out-of-the-box' which then lead to 'out-of-the-box' ideas.

The typical response from the traditional minded people is that we may never reach there. While this may be true in many cases, there have been quite a few instances when the teams have gone even beyond such impossible goals. Most of those who have not succeeded in doing so, have at least gone well beyond their usual ways of generating ideas.

While OSI is strongest in this stage, other methods also provide many inputs to complete this stage and build the belief that pursuing the impossible will still yield possible outcomes and the efforts will certainly not be totally wasted. Some techniques from other methods that are useful are:

- SI/TRIZ: Ideal-Final-Result, Evolution Potential Trends, Perception Mapping
- B3.8: Taxonomy & Li fe Principles that bridge functions of nature with those of other domains

Integrating many approaches like the BMI, OSI etc., MIND™ has also evolved its own approach for mapping the eco-system which is useful when the starting intent is to find opportunities to either innovate a new eco-system or a new business / operating model in the current eco-system.

3.2 Ideate

Most methods rely a lot on the team's natural ways of ideation supported by fixed set of triggers like words, phrases, cards based on research studies etc. Some of them also have generic principles that suggest the teams to hold back their thoughts which would limit the ideation process e.g. Park-your- Judgement (OSI), Quieting-the-cleverness (B3.8) etc.

The most powerful and systematic way of ideation has been observed through a combination of three methods:

- OSI: 3-gear ideation techniques provide ways to recognise and shift mindset through systematically going deeper into own ways of ideation, identifying & questioning the fundamental ways of thinking and learning from other domains. This also includes the Orbit-shift-insighting mentioned earlier but at this stage the technique is setup to uncover the insights that would trigger a solution that would be adopted by stakeholders.
- SI/TRIZ: 40-principles supported by Contradiction Matrix database and Patent Inspiration provide ways to identify the right patents to review for direct solution or at least trigger a new direction of thinking for the solution.
- B3.8: Taxonomy supported by their sister non-profit-organisation, Ask Nature's database of solution strategies provide triggers for new solution directions which may have never been thought of before by mankind.
- Open Innovation / Crowd sourcing platforms have a separate offering for getting a theoretical solution only and can be leveraged at this stage.

As it is said, 'ideas are available a dime a dozen' and although powerful are not useful until and unless these are converted in solutions that meet the stated or unstated needs of all stakeholders. In line with this philosophy, MIND™ has integrated frameworks & templates from multiple sources to hold a consolidated set and leverage the most relevant set for the context. Some examples of these are Stakeholder segmentation / profiling /persona, Proposition Modelling including visual representation of existing and new solutions etc.

3.3 Nurture

This stage is often referred to prototyping / testing / validating / many other variants of these. For MIND™, we have chosen to call it nurturing as a new & innovative solution would rarely be right the first time and hence will have to be evolved through many iterations which may or may not include pivoting to a completely different avatar.

Unlike the previous stages which focus heavily on the thinking process which is domain-agnostic, Nurture is the stage where domain knowledge begins to play a critical role and hence needs to complement the innovation methods. Most methods have very generic principles for this stage e.g. Fail-early-safe-cheap, Do-it-in-stages-Best-Real-Scaleup, Build-low-fidelity / frugal prototypes, Leverage-the-Positives, Amazon's 'Two-pizza' theory etc. Then there are some methods like the Design of Experiments which need to be contextualised to each task specifically.

Apart from all the above, MIND™ has evolved its own experiential principle of 1-2-5 stages of evolution wherein the solution needs to be nurtured in steps of 1-2-5 in each range of scale e.g. do what can be done by:

- People: First by 1 person, then by 2 people and then 5. Thereafter by 10-20-50 and so on.
- Money: 10k-20k-50k, 100k-200k-500k
- Time: 1-2-5 days, weeks, months years

Each team in alignment with their key sponsor can decide on the starting & ending scales. This principle has helped teams to focus on following all the principles effectively.

Open Innovation approaches would be useful for evolving a technology prototype. However, the project team will have to take full responsibility of doing the consumer acceptance prototyping & evolution.

Also useful is OSI's Orbit-shift-insighting techniques which at this stage is required to be setup to evolve the solution that all the stakeholders would easily adopt. The end outcome of this stage is a working model which needs to be scaled-up in the Deploy stage.

3.4 Deploy

This is the stage where the most domain and operations management methods take-over the dominant role. The innovation methods play a very limited role. Some areas where MIND™ has been able find space are gradual scale-up where Orbit-shift-insighting of OSI is has pl ayed a key role to uncover finer insights that are specific to the stakeholders of the areas where the scale-up is intended or has not achieved aspired impact.

Once the finer insights are uncovered, Ideation & Nurturing methods are again leveraged to generate & evolve solutions to meet the specific requirements of that area.

3.5 Project navigation

While most methods focus on each of the stages discreetly, the overall navigation is often left to 'stage-gate' like processes. OSI emphasises on periodic stakeholder alignment with an intent to prioritise and evolve the new concept to its maturity. Apart from the flow, OSI also covers techniques to build such alignments.

Another principle that is often mentioned while managing the overall flow of a project is diverge-converge-repeat. This is also covered with relevant & guiding techniques of ideation & synthesis which also gives a sense of closure to each stage giving a sense of progress in the inherently iterative & seemingly unending loops.

4. Impact / Outcomes

Note: For confidentiality, the sanitized data are presented in this paper. The outcomes mentioned here are only from the period of January 2017 till March 2020.

Over the past 3 years since this method has been evolved, over 2,000 out of the 10,000 officers have leveraged MIND™ to deliver over 100 projects.

Amongst these are two internal start-ups viz. Road Trippers Co (www.theroadtrips.co) & Glyd (www.myglyd.com), were shaped during their early stages. Apart from these, at least five new patents are filed & many high-potential concepts evolved, which are in various stages of development.

Also, as a part of this initiative, more than 150 officers have registered to become Innovation Ambassadors and about 20 have registered to become Innovation Multipliers. Two units have established Innovation Cells and more have expressed interest.

MIND™ has also been successfully integrated with other initiatives e.g. the Mahindra Black Belt program – a customised Six-Sigma based program, Talent Management Programs etc. Some leaders are establishing MIND™ based awards across all their units.

A summary of the key realizations synthesized from of the ones share by those who have experienced MIND™ is as follows. According to them, MIND™ has helped to:

- systematically reframe the problem statement & question the status quo

- get clarity & direction on ambiguous projects
- uncover deeper understanding of needs from people in the ecosystem
- reactivate of some projects that were about to be shelved
- voluntarily raise targets; often well beyond the stretched level of performance measures
- generate immediately implementable ideas and savings have already accrued
- generate an of average 2x more solutions than other methods

4.1 Some sanitized examples are:

While working on a design for a seat on a field equipment, a team had identified a contradiction for reach vs comfort. By applying OSI, the need for seat itself was questioned and at a higher level of abstraction, the need for a person to be on the equipment was questioned. Both these set of questions enabled the team to look for a different way to provide comfort to the operator and identify another project with a design where no operator would be required to travel on the equipment.

While working on a project to improve strength of sheet metal parts, Biomimicry resources were being leveraged to find solution strategies from nature's ways of doing so. During the search, the team came across a strategy where a pigment provides strength to the base material. Though the strategy was not very relevant to the context of the project, it shifted the mindset of the team that pigment can also be used for strengthening a base material. So far, it was being used only for protection and aesthetics purpose and a new project was launched to leverage this strategy.

While working on a project to reduce material cost of an equipment, the usual ideation process had just about 25% of the required target reduction. MIND™ techniques enabled the team to bridge the gap. Then, OSI helped the team to pick-up a fundamental way of designing that equipment which the entire industry was following. Then TRIZ & Biomimicry helped the team to identify at least 10 different ways in which the same purpose of the equipment can be achieved. About 5 of these were prototyped and were found to yield better performance than the industry standard way of doing it.

4.2 Testimonials

From leaders of bu sinesses / functions that leveraged MIND™:

Aravind Bharadwaj, Chief Technology Officer, Automotive & Farm Equipment Sectors:

"Our Advanced Technology team has been dealing with the pipeline of projects which focus on getting into the mainstream within 2 to 3 years. While we manage the pipeline well, the MIND™ team has been a critical enabler in continuously feeding it so that we never run dry. We are also seeing traction for the method by our technology & product development teams for questioning the fundamentals & understanding the consumers at a deeper level."

Rustom Vesavevala, Vice President – Human Resources & Business Excellence, Mahindra Partners Sector:

"MIND™ has been successful across many businesses of the Group which are diverse in terms of size, life-cycle and industries. While the businesses are experiencing higher outcomes with MIND™, we have also initiated the development of people who can enable us to cascade these benefits faster. The outcomes are giving us confidence that our intent of institutionalizing innovation culture will soon become a reality in our organization."

Ashok Sharma, President Agri Sector & Head of Innovation for Automotive & Farm Equipment Sectors:

"MIND™ is a very comprehensive and easy to understand approach to innovation. We have been able to democratise innovation across a very diverse set of businesses. The feedback received from every business for this approach has been very positive and they have been able to deliver higher business results with MIND™" –

Dr Pawan Goenka, Managing Director, Mahindra & Mahindra Limited:

"I have always wanted innovation not to be limited to a select few, but something that everyone in the organisation has to be doing in their own way & space. MIND™ has enabled that to happen. I see some fascinating work being done. While the core innovation team is driving few critical projects, there is a visible pull for the MIND™ approach from across the organisation."

5. Conclusions

Using each method independently or discreetly at relevant stages of innovation does yield good results. Integrating these seamlessly and customising to suit each context yields higher impact and eases the ability to institutionalise it.

It will be futile to compare the methods to find the strengths and weakness as the intent it to leverage the strengths of each in the particular context and as it is said in innovation, one must operate with a 'need back' approach rather than a 'process or solution forward' one.

6. Acknowledgements

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The author would like to thank the senior leaders at Mahindra & Mahindra Ltd., for their partnership in trying out different versions of MIND™ in their business / functional areas. This work of integration, harmonization and evolution would not have been possible without their active support.

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Exploring the Influence of Innovation Management Tools on Product Innovation- the Case of Peruvian Innovative Firms

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Abstract

This paper investigates the influence of innovation management tools on product innovation in 84 Peruvian companies that received public funding to carry out innovation projects. The empirical exploratory study is based on a comprehensive questionnaire for collecting data and is analysed using a binary Probit method. The results indicate that although the use of tools is scarce in Peruvian companies, innovation management tools influence product innovation. Furthermore, all the evidence shows that innovation management is important, and therefore the innovation process must be structured and systematized.

Keywords: Innovation Process; Innovation Management; Product Innovation; Tools.

1.Introduction

Innovation management has gained popularity in research and practice because of its positive effects on firm performance (Khosravi, Newton and Rezvani, 2019). Therefore, there is a body of empirical research which supports the notion that utilizing appropriate tools can assist firms to achieve better performance when launching new products (Cooper and Edgett, 2008). Keupp, Palmié and Gassmann (2012) suggest that the strategic management of innovation is concerned with using appropriate strategic management techniques and measures to augment the impact of the firm's innovation activities on its growth and performance (p.368). Our study analyses to what extent firms' product innovation is enhanced by innovation management tools, especially when NPD tools are an important driver of successful innovation (Keupp et al., 2012; De Waal and Knott, 2019). This raises the following research question: Is there a relationship between the innovation management tools and product innovation? Although literature is extensive and varied on the NPD process and successful new product outcomes (Cooper, 2019), analysis on NPD tools (De Waal and Knott, 2019) or innovation management tools (Keupp et al., 2012) has received less attention, especially in emerging economies. Thus, our research contributes to understanding whether the use of innovation management tools and product innovation are related in emerging contexts.

From a technical perspective, one of the main barriers to conducting studies on innovation in Peruvian companies is the lack of databases with up-to-date contact information, as well as the lack of confidence in and diffusion of the innovation topic (Yrigoyen, 2013). The strategy to reduce this obstacle was to contact institutions that have developed a link with these companies. Using this method, the empirical exploratory analysis is based on a sample of 84 Peruvian innovative firms that were financed with public funds to develop innovation projects. A comprehensive questionnaire for collecting data is used and is analysed through the binary Probit method. The results illustrate that there is a relationship between the use of innovation management tools and product innovation. Furthermore, the evidence shows that innovation management is important, and therefore the innovation process must be structured and systematized (Tidd, Bessant and Pavitt, 2005; Martínez-Costa, Jimenez-Jimenez and Castro-del-Rosario, 2018).

The structure of the paper is as follows: The next section introduces the literature review and conceptual framework on innovation management, which then leads to the research hypotheses. The third section details the databases and tests the assumptions. The empirical results are provided in the fourth section. Finally, the fifth section provides some brief conclusions, limitations, and future research.

2.Conceptual Framework and Hypotheses

2.1 Innovation Process

Based on the Oslo Manual (OCDE and EUROSTAT, 2005), innovation can be understood as a final product or process that makes it possible to combine technical, financial, productive, organizational, and commercial capabilities to create or improve a product. On the other hand, research and practice in the innovation process have been deeply influenced by certain models that play different roles and influence decisions, as well as indicating good management practices (Salerno, De Vasconcelos-Gomes, Da Silva, Bagno and Freitas, 2015). Many studies have sought to understand the innovation process, but scholars have not yet been able to identify a clear prototypical process for the management of innovation (Gupta, Tesluk and Taylor, 2007). Innovation can be understood as a process that transforms specific inputs into outputs (Tidd et al., 2005; Sattler, 2011). In this vein, several authors have classified these activities using their own conceptual model of the innovation process (Sattler, 2011). For Damanpour (1991) the innovation process has three stages: the generation, development, and implementation of new ideas. Cooper, Edgett and Kleinschmidt (2002) found that many successful companies employ formal innovation processes with well-defined decision criteria, which can be composed of different phases and subprocesses, from the generation of ideas to the launch of the new product onto the market. Bessant and Tidd (2011) state that this process starts with a new idea and ends with the end user through marketing and commercialization activities. Therefore, since innovation appears to be seen as a process, various authors made their contributions on the stages of this process with certain similarities and differences in the limitations, quantity or denominations of each stage (Seclen-Luna, 2019). In any case, having some kind of innovation process is better than not having any process at all (Kahn, 2019).

Based on models that are currently widely accepted and referenced for their practical relevance, such as Cooper's 'Stage-Gate' (2014) and Gaubinger, Rabl, Swan & Werani 's (2014) model, we can understand that a 'standard and basic' innovation process has at least five phases that are interactive and simultaneous: management of ideas, product concept, product development, product implementation and product commercialization (Seclen-Luna, 2019). Though a unique model does not exist, as it cannot be generalized or followed by many companies, the 'standard and basic' innovation process attempts to show the importance of the innovation process since many companies successfully employ different types of innovation processes (Cooper et al., 2002; Tidd et al., 2005).

2.2 Innovation Management

Although there is considerable literature showing that competitive success depends on the management of innovation in an organization (Dodgson, Gann and Phillips, 2014), the few structured studies on this topic have not been able to establish a consensus on the nature of innovation management (Adams, Bessant and Phelps, 2006). This is mainly because companies are heterogeneous and can apply different strategies to manage their innovation process (Seclen-Luna and Barrutia-Güenaga, 2019). Martínez-Costa et al., (2018) state that the implementation of the standardized innovation management systems (e.g. UNE 166.000) promotes all types of innovations.

Innovation management has gained increased popularity in research and practice because of its positive effects on firm performance (Khosravi et al., 2019). In this way, a body of empirical research supports the notion that utilizing appropriate tools can assist firms to achieve better performance in launching new products (Cooper and Edgett, 2008). Therefore, the use of tools (methods and techniques) can help to create successful innovation management, particularly, after having been tested and refined by organizations according to their specific situation (Alegre, Lapiedra and Chiva, 2006) and the inclusion of relevant indicators (Dziallas and Blind, 2019). In the same vein, Keupp et al., (2012) suggest that the strategic management of innovation is concerned with using appropriate strategic management techniques and measures to augment the impact of the firm's innovation activities on its growth and performance (p.368).

Although in previous studies a list of 76 established tools haves been identified from the literature (De Waal and Knott, 2010), we believe that the selected tools differ widely in levels of abstraction and discipline base, and collectively they represent a broad scope of innovation activity areas. Thus, we did not set out to include all existing innovation management tools (Table 1), but to cover a full set of categories of tool functions in the context of 'conventional' business innovation (Seclen-Luna and Barrutia-Güenaga, 2019).

Table 1 Innovation Management Tools

Phase of Innovation Process	Tools
Management of Ideas	Brainstorming TRIZ Collaborator's mailbox ideas FMEA Customer surveys Strategic surveillance Focus groups Patents analysis
Product Concept	Design and simulation Cost-Benefit analysis Target costing Road-mapping
Product Development	R&D costing PERT Road-mapping QFD
Product Implementation	Production test Quality audits Six Sigma 5 S
Product Commercialization	Advertising Press conference Sales test Post-Launch analysis

In this research, following the 'standard and basic' innovation process, we focus on the use of those tools that are most used in the management of the innovation process (Dornberger and Suvelza, 2012; Seclen-Luna and Barrutia-Güenaga, 2019), as explained below. During the first phase, management of ideas, the use of the collaborators' mailbox, the brainstorming method for the generation of ideas (Moulin, Kaeri, Sugawara and Abel, 2016), the TRIZ method (Ilevbare, Probert and Phaal, 2013) and the Failure Mode and Effects Analysis (Behrani, Bazzaz and Sajjadi, 2012) for the selection of ideas, can help to select and evaluate ideas effectively. On the other hand, for the adequate search for ideas, opportunities and environmental threats, some basic methods are used such as the customer satisfaction survey (Morgan, Obal and Anokhin, 2018) and the focus groups. These can be complemented with other more advanced techniques, such as patent analysis (OuYang and Weng, 2011) and strategic surveillance, which are powerful tools that involve a deliberate comprehensive analysis of various actors and factors related to the company wishing to innovate (Seclen-Luna and Barrutia-Güenaga, 2019). Therefore, based on these arguments, the following hypotheses is offered:

Hypothesis 1: The use of tools for the management of ideas is associated with product innovation.

In the second phase, the concept of the product, the initial evaluation and the planning of activities are carried out, preparing the conditions for the execution of the project in a precise, coherent, and objective manner (Jissink, Schweitzer and Rohrbeck, 2019). Road-mapping is a very useful tool since it articulates foresight, direction and strategic planning in an integral way (De Alcantara and Luiz Martens, 2019). Furthermore, the use of plans, designs and simulation is important for the proof of the concept of a new product, since the preliminary technical viability of the product is verified (Ulrich and Eppinger, 2015). In recent years, the target costing for the economic-financial analysis, separate from the traditional cost-benefit analysis, has become one of the most commonly used tools by the most competitive companies due to its high effectiveness (Afonso, Nunes, Paisana and Braga, 2008). Therefore, based on these arguments, the following hypotheses is offered:

Hypothesis 2: The use of tools for the product concept is associated with product innovation.

In the third phase, product development, the management of R&D and technology acquire special relevance, since it has as a starting point the knowledge that the company has accumulated over time (Sattler, 2011). One of the most used techniques of support is the R&D costing, which consists of making a costing per unit of R&D, process, or activity (Lee, Jeong and Yoon, 2017). Furthermore, the PERT methodology (Mazlum and Güneri, 2015), the road-mapping for R&D activities (Yoon, Kim, Vonortas and Han, 2019), and the QFD method (Eldermann, Siirde and Gusca, 2017), are highly recommended. In short, this phase is important for the validation of the product which is 'materializing'. Therefore, based on these arguments, the following hypotheses is offered:

Hypothesis 3: The use of tools for product development is associated with product innovation.

The fourth phase, product implementation, begins with production tests where flexibility and control of production costs are required. However, if the product is new it could cause changes in the technical specifications, affecting the production process (Seclen-Luna and Barrutia-Güenaga, 2019). During the production process, it is essential for quality management to detect, analyse and find solutions to the problems that arise in the work area through quality audits and the 5S method (Heras,

Marimon and Casadesús, 2009). Furthermore, the use of advanced management methods such as the Six Sigma, are of great help and importance in the production phase (Parast, 2011). Therefore, based on these arguments, the following hypotheses is offered:
Hypothesis 4: The use of tools for product implementation is associated with product innovation.

The fifth phase, commercialization of the product, is characterized by launching a timely introduction of the new product to the market (Hansen and Birkinshaw, 2007). To do this, from the concept of the product the identification of consumer needs should have been raised and, in this phase, is complemented and deepened with operational marketing activities of a functional type. However, many of these activities are mixed for greater effectiveness. In this phase, the most common is the use of advertising and sales testing (Cooper, 2019). The percentage of sales that comes from the launch of the new product must also be known. Therefore, based on these arguments, the following hypotheses is offered:
Hypothesis 5: The use of tools for product commercialization is associated with product innovation.

Fig.1 presents the hypotheses formulated in a relationship model. The next section addresses the study methodology.

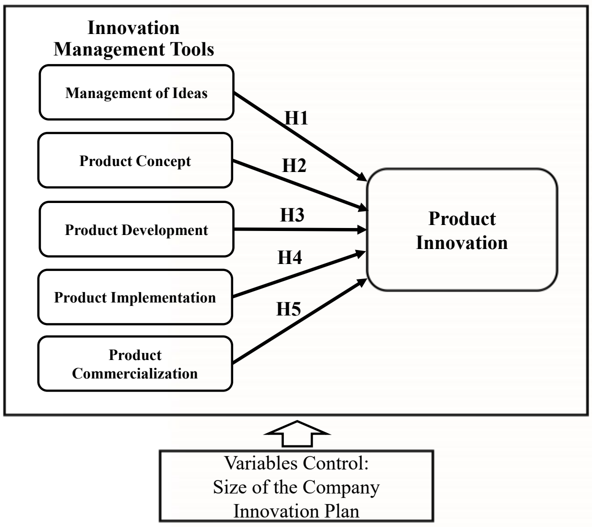

Fig.1 Relationship Model

3. Data Collection and Methodology

3.1 Data Description

In the decade 2005-2015, Peru had an average growth of 5.5% of its GDP and shows a macroeconomic strength. Its economic growth was driven by private investment. In fact, Peru ranks second in Latin America and the Caribbean as one of the best countries to do business with (World Bank Group, 2015). In terms of competitiveness, Peru is ranked 65 out of 143 countries according to the Global Competitiveness Report 2014-2015 but is ranked 116 in the Innovation Index (World Economic Forum, 2015). In the same vein, one of the main barriers to conducting studies on innovation in Peruvian companies is the lack of databases with up-to-date contact information, as well as the lack of confidence in and diffusion of the innovation topic (Yrigoyen, 2013). The strategy used reduce this obstacle was to contact institutions that have developed a link with these companies.

To ensure that the companies are innovative, we selected the Peruvian companies that were financed with public funds to carry out an innovation project. According to Innóvate Perú (executing agency of the Ministry of Production of Peru), the PIPEI, PITEI, PIMEN and PIPEA programs aim to strengthen the technological capacity for innovation in companies through the financing of innovation projects for the creation of a new product or process and its successful introduction into the market.

Between 2013 and 2015, 107 companies throughout Peru were financed by these programs and completed their respective innovation projects. Therefore, we assume that they have innovation capabilities. The final sample was 84 companies (of which 84% had less than 50 workers and 16% had more than 50 workers) obtaining a response rate of 78%. Table 2 summarizes the sample composition of firms. In this study, the unit of analysis is the innovation management. This choice is made because a company may have a different innovation process (Salerno et al., 2015) and use diverse tools for their innovation management (De Waal and Knott, 2010; Keupp et al., 2012; Dornberger and Suvelza, 2012; Seclen-Luna and Barrutia-Güenaga, 2019).

Table 2 Sample Composition (Percentage)

Industrial Branch	Firms
Software and Hardware Services	20.24
Metalworking Industry	10.71
Wood Industry	3.57
Transport Services	3.57
Business Consulting Services	11.90
Agroindustry	20.24
Ceramic Industry	3.57
Surgical Equipment Industry	3.57
Engineering Services	5.95
R&D Services	8.34
Others	8.34
Total	**100%**

To verify the hypotheses proposed, the empirical research was based on a probabilistic sampling of online surveys directed to the manager of the company or R&D director who participates in the decision-making for the company. The survey was carried out from April to July 2017 and contains a set of questions organized into three sections: the first focuses on the general characteristics of the companies, such as the type of property, manager's characteristics, number of workers, etc. The second section refers to innovation in the company where the focus is on the reasons why companies carry out innovation activities, as well as on the different types of expenses related to innovation and the innovation outcomes obtained in previous year before the survey. The third section focuses on the innovation process of companies, emphasizing the activities carried out and the use of tools for innovation management. In total, the questionnaire contained 27 questions that were initially tested for their content and structure through a pilot test with 10 companies.

3.2 Description of Variables

The dependent variable is product innovation and is measured through a dummy variable where the firm reported the carryout innovation over the last year. The independent variables are all the tools mentioned, according to the five phases of the innovation process, and is measured through a Likert scale of three points: 1 = non-use; 2 = occasional use; 3 = very frequent or systematic use. The positive scale values (from '1' to '3') allows a sufficient degree of differentiation in the valuation of the analysed variables. In addition, it is important to clarify that in this section of the questionnaire, in these questions there was an 'other' option where the respondent could indicate the use of another type of tool. In terms of the analysis of the internal consistency of the scale, an alpha Cronbach value of $\alpha = 0.635$ was obtained for the first phase, $\alpha = 0.751$ for the second phase, $\alpha = 0.879$ for the third phase, $\alpha = 0.647$ for the fourth phase, and $\alpha = 0.713$ for the fifth phase, which indicates a considerable reliability level in all variables. Table 3 provides a definition of the variables used in this study.

Table 3 Definition of Variables

Variable	Definition	Scales
Product Innovation	Firm reported the carryout innovation during the last year	Dichotomous
Tools	Any structured aids, managerial or technical in nature, that support the innovation processes	Ordinal
Innovation Plan	Firm reported that it has a plan to carryout innovations	Dichotomous
Firm's size	Number of total workers	Logarithm

3.3 Method and Regression Model

In accordance with our research objectives, we estimate the relationship between innovation management tools and product innovation, using the Binary Probit method by Eviews. The equation describing this relationship takes the form:

$$Product\ Innovation_i = \beta_0 + \beta_1\, IMTools_i + \Omega_i + \vartheta_i + \varepsilon_i \quad (1)$$

…where the sub-index i refers to the firms. $IMTools_i$ is a vector of innovation management tools. Ω_i refers to size (nº workers), ϑ_i refers to the innovation plan; and ε_i is the error term. Furthermore, in accordance with the aims of the research at hand, we used the principal regression model (1) to depict how innovation management tools are related to product innovation. That is, we adjusted a regression for each phase of the 'standard and basic' innovation process, assuming as independent variables, the innovation management tools and their influence on product innovation. In addition, we use the Binary Probit method due to the data being cross-sectional.

4. Result and Discussions

From a descriptive perspective, the first characteristics to highlight in the companies analysed are that they do not have an innovation plan (55%). Despite this, the results indicate an average of 72.6% of the companies carried out product innovation in the last year, obtaining an average of 2 new products each. Furthermore, regarding the innovation management, the use of tools is scarce (Table 4). For instance, in the fuzzy-front end of the innovation process, in the generation of ideas, on average 62% of companies do not use the collaborators' mailbox to generate ideas, 58% of companies do not use the TRIZ methodology to generate and solve problems, and the FMEA is also not widely used by companies (63%).

Table 4 Use of Innovation Management Tools (Percentage)

Phase of Innovation Process	Tools	Non-Use	Occasional Use	Systematic Use
Management of Ideas	Brainstorming	37	30	33
	TRIZ	58	28	14
	Collaborator's mailbox ideas	62	32	6
	FMEA	63	30	7
	Customer surveys	45	36	19
	Strategic surveillance	43	32	25
	Focus groups	60	22	18
	Patents analysis	81	17	2
Product Concept	Design and simulation	42	26	32
	Cost-Benefit analysis	35	38	27
	Target costing	50	30	20
	Road-mapping	62	27	11
Product Development	R&D costing	58	16	26
	PERT	56	12	32
	Road-mapping	60	21	19
	QFD	70	10	20
Product Implementation	Production test	38	31	31
	Quality audits	46	39	15
	Six Sigma	85	14	1
	5 S	65	24	11
Product Commercialization	Advertising	45	33	22
	Press conference	71	25	4
	Sales test	57	31	12
	Post-Launch analysis	56	31	13

On the other hand, the results indicate that a firms' decision to use tools in their NPD process, is a critical determinant of their product innovation. In this way, equation (1) is estimated. Tables 5, 6, 7, 8 and 9 show the regression models of innovation management tools and product innovation, as explained below.

Table 5 Regression Model (Management of Ideas Phase)

Variable	Product Innovation Coefficient	Prob.
(Intercept)	-1.104790	0.3119
Size of the company	0.083583	0.7835
Innovation plan	0.203580	0.6908
Brainstorming	1.036451	0.0041
TRIZ	0.090334	0.7972
Collaborator's mailbox	0.074133	0.8564
FMEA	1.229219	0.0181
Customer surveys	-0.637204	0.1177
Strategic surveillance	0.252537	0.4201
Focus groups	-0.699512	0.0265
Patents analysis	-0.260144	0.6110
R-Squared (McFadden)	0.42	

According to the information shown in the previous table, we can distinguish two significant findings. First, that not all innovation management tools at the 'management of ideas phase' are relatively important. That is, there are certain tools such as brainstorming, FMEA and focus groups that are significant in the model. Therefore, these results show that there are differences between the innovation management tools of the 'management of ideas phase'. Second, even though the brainstorming, focus group and FMEA tools are significant, there are few companies that used these innovation management tools more frequently, for example, brainstorming (33%), focus group (18%) and FMEA (7%). One possible explanation for this non-use of tools may be due to the fact that the companies do not have personnel to be in charge of innovation activities (in fact, the companies analysed have an average of 5 workers dedicated to innovation activities). Likewise, SME owners are often unfamiliar with these techniques or do not find their value adequate for their needs. In this way, owners tend to be more intuitive and informal in the way they manage their innovation. In any case, the use of each technique or tool will depend on the knowledge and experience of the manager or person responsible, as well as the collaboration between the different areas or departments of the company (Hansen and Birkinshaw, 2007). Despite this, there is an association between these innovation management tools and product innovation. Therefore, these results support Hypothesis 1 and coincide with previous studies, such as those of Behrani et al. (2012) and Moulin et al. (2016), who found that both FMEA and brainstorming each have an influence on product innovation, respectively. Lastly, all this evidence suggests that the 'management of ideas phase' is relevant in the innovation process (Damanpour, 1991; Cooper at al., 2002; Bessant and Tidd, 2011).

Table 6 Regression Model (Product Concept Phase)

Variable	Product Innovation Coefficient	Prob.
(Intercept)	0.094287	0.8783
Size of the company	0.271563	0.1673
Innovation plan	-0.008233	0.9807
Design and simulation	0.148285	0.4569
Cost-benefit analysis	0.291792	0.2804
Target costing	-0.049890	0.8625
Road-mapping	-0.474415	0.1209
R-Squared (McFadden)	0.06	

As can be seen in Table 6, despite the fact that, on average, the analysed companies use these innovation management tools, these tools of the 'product concept phase' are not relevant in this phase due to the fact that we do not find these variables significant. One possible explanation for this is that Peruvian companies do not usually conduct consistent and appropriate technical, financial and market evaluations (Alvarado-Alarcón, Alegre-Valdivia, Martínez-Utía and Seclen-Luna, 2018). Hence, the innovation management tools considered in the model could not explain the probability of effect on product innovation. In fact, the tools analysed do not show any association with product innovation. Therefore, these results do not support Hypothesis 2. By contrast, many studies find that in this phase, the technical and financial assessment through cost-benefit analysis among other techniques is required (Ulrich and Eppinger, 2015). Even Cooper (2017) includes the evaluation of possible environmental, safety, health, and other problems, in his so called 'Build Business Case'.

Table 7 Regression Model (Product Development Phase)

Variable	Product Innovation	
	Coefficient	Prob.
(Intercept)	1.375607	0.0113
Size of the company	0.304949	0.1381
Innovation plan	0.980256	0.0430
R&D costing	0.395217	0.2794
PERT	0.005693	0.9843
Road-mapping	-1.041318	0.0204
QFD	-0.405848	0.2098
R-Squared (McFadden)	0.21	

According to the information shown in Table 7, we can distinguish two important findings. First, that not all innovation management tools at the 'product development phase' are important. In particular, we find that road-mapping is more important than other tools. Second, even though, on average, 19% of the companies analysed use this innovation management tool, we found that there is an association between road-mapping and product innovation. Therefore, these results support Hypothesis 3 and concur with previous studies, such as those of Yoon et al. (2019), who found that road-mapping presents relationships with product innovation. In any case, all this evidence suggests that the 'product development phase' is relevant in the innovation process (Sattler, 2011). On the other hand, the innovation plan is significant in this phase of the innovation process, while the size of the company is not significant. Perhaps a possible explanation for this result is that Peruvian companies have low levels of investment in R&D (Heredia-Perez, Geldes, Kunc and Flores, 2019; Seclen-Luna, Ponce and Cordova, 2020).

Table 8 Regression Model (Product Implementation Phase)

Variable	Product Innovation	
	Coefficient	Prob.
(Intercept)	1.160529	0.0665
Size of the company	0.707212	0.0097
Innovation plan	0.585658	0.2431
Production test	0.338504	0.2452
Quality audits	0.253739	0.3916
Six Sigma	-2.071047	0.0002
5 S	-0.383201	0.2113
R-Squared (McFadden)	0.27	

According to the information shown in Table 8, we can appreciate two main findings. First, that not all innovation management tools at the 'product implementation phase' are important. In particular, we find that Six Sigma is more important than other tools. Therefore, these results show that there are differences between the innovation management tools of the 'product implementation phase'. Second, even though, on average, 85% of the companies analysed do not use this tool, we found that there is an association between Six Sigma and product innovation. Therefore, these results support Hypothesis 4 and concur with previous studies, such as those of Parast (2011), who found a relationship between the use of the Six Sigma and the innovative performance of companies. In any case, all this evidence suggests that the 'product implementation phase' is relevant in the innovation process (Seclen-Luna and Barrutia-Güenaga, 2019). On the other hand, the firm size is also significant in this phase of the innovation process. This is consistent with several studies which highlight that large enterprises have more opportunities to implement innovation activities (Annacchino, 2007; Leal-Rodríguez, Eldridge, Roldán, Leal-Millán and Ortega-Gutiérrez, 2015).

Table 9 Regression Model (Product Commercialization Phase)

Variable	Product Innovation	
	Coefficient	Prob.
(Intercept)	0.722110	0.2100
Size of the company	0.326771	0.1054
Innovation plan	-0.003522	0.9916
Advertising	0.289133	0.0229
Press conferences	-0.581700	0.0550
Sales test	-0.065972	0.8315
Post-launch analysis	-0.185228	0.5045
R-Squared (McFadden)	0.10	

According to the information shown in Table 9, we can distinguish two significant findings. First, that not all innovation management tools at the 'product commercialization phase' are important. In particular, we found that advertising is more important than other tools. Therefore, these results show that there are differences between the innovation management tools of the 'product commercialization phase'. Second, even though, on average, 22% of the companies analysed use this tool, we found that there is an association between advertising and product innovation. Therefore, these results support Hypothesis 5 and concur with previous studies such as those of Cooper (2019), who found a relationship between the use of advertising and the launch of a new product. In any case, all this evidence suggests that the 'product commercialization phase' is relevant in the innovation process (Hansen and Birkinshaw, 2007; Cooper, 2019).

5. Conclusion, Limitations and Future Research

5.1 Theorical Implications

Understanding the interplay between innovation management tools and product innovation (Keupp et al., 2012; Martínez-Costa et al., 2018) demands a conceptual framework that would help us understand these relationships in a context of emerging countries. The present research examines these relationships in Peruvian innovative firms to corroborate traditional theories that apply to Western economies on these issues. The evidence presented in this paper provides empirical support that there are relationships between the use of innovation management tools and product innovation; particularly in the management of ideas phase, brainstorming, the FMEA and focus groups. In the product development phase, road-mapping is particularly important whilst in the product implementation phase, it is the Six Sigma. In the product commercialization phase advertising is significant. However, in the product conceptualization phase no relationships have been evident. In any case, our findings go beyond established research into whether or not firms use particular NPD tools by considering the thoroughness of tool usage from a theoretical standpoint. All this evidence shows that innovation management tools do have an influence on product innovation (Keupp et al., 2012; Martínez-Costa et al., 2018; De Waal and Knott, 2019).

5.2 Managerial and Policy Implications

This study contains two main implications; the first is suggesting that even though non-thorough use of NPD tools is commonplace in small firms, the use of innovation management tools has a positive influence on product innovation (Martínez-Costa et al., 2018; De Waal and Knott, 2019). Furthermore, all the evidence shows that innovation management is important, and therefore the innovation process must be structured and systematized (Tidd et al., 2005; Martínez-Costa et al., 2018; Seclen-Luna, 2019). The second implication suggests that it is important for regional and local governments to consider integrating links with external actors (i.e. KIBS or specialized suppliers, universities, etc.) to design an innovation policy for promoting the innovation management of companies, particularly the smaller ones, since KIBS can compensate or complement the innovation capabilities of their client companies (Muller and Zenker, 2001; Seclen-Luna and Barrutia-Güenaga, 2018).

5.3 Limitations and Future Research

Although these results are useful for their implications for business managers and policy makers, since it advances knowledge about how innovation process should be managed by companies (García and Calantone, 2002) in the Peruvian context, this study has limitations that suggest the need for future research. Firstly, owing to the sample only being made up of innovative companies financed by public programs, these results cannot be generalized, so they should be taken with some caution. Secondly, because the analysis carried out in this exploratory study is of a cross-sectional nature, it leads to the failure of trying to capture all the dynamics of the innovation process. For instance, to understand how companies make decisions for using a tool, we need to ask them how the implementation of an innovation process affects them, or even: Does the innovation process affect them? This question remains open for future research. Third, despite the relationships which are significant in our models, other factors not included in the current models may also play an important role. Thus, future research will need to corroborate the results in specific contexts (at sectoral and regional levels) in a long-term analysis to determine some of the causal mechanisms. Finally, it would also be very worthwhile to carry out comparative studies among emerging countries, which would help governments to improve their policies promoting innovation management.

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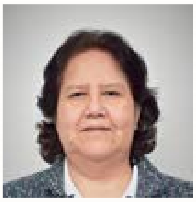

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Research on Technology-function Matrix Construction for Patent Layout

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Abstract

Technology-function matrix (TFM) is one of the most important methods of patent layout. The establishment of the TFM can help enterprise managers to make technology layout and market decision. In order to realize the information visualization and automatic construction of TFM, most of the researches focus on sematic annotation technology. The data for the construction of TFM are published patents. But research on the relationship between patents and TFM is insufficient. Considering the deficiency of current research, based on customer requirements and technology life cycle method, a TFM method is proposed. Firstly, customer requirements are accessed by Kano model, and then TFM is established by narrowing the technology domain through technology life cycle diagram. An engineering case is provided to verify the feasibility of the approach.

Keywords: customer requirements, patent layout, technology-function matrix, technology life cycle

1. Introduction

Patent text is the carrier of detailed design information to the public, and it is the most effective way to obtain technical information. How to query the target technical field in large number of patent texts are the issues faced by technicians at present. Patent technology-function matrixes are widely used by technicians among all technical management and analysis tools. It is a kind of patent map, which has advantages in information visualization.

Technicians annotate the patent text. The "technology" and "function" involved in the indexing patent instructions. Merging the similar technical efficacy of different patents, and finally draw the TFM. The matrix statistical tables or diagrams is used to analyze the technical skill and achieving efficacy. The rule of making a matrix is achieving efficacy as the vertical axis, and the technical skill as the horizontal axis. The number of patents or patent number is generally used in tables or diagrams.

Enterprise managers use matrix diagrams to make patent layout, discover technological opportunities, evade minefields, and discover core patents in the specific technical field. Many of the experts and scholars have studied how to improve and perfect the TFM. Kim et al. (2008) had put forward a new method of patent map visualization, established a keyword semantic network without considering filing date, took into account both structured and unstructured items of patent documents, and summarized patent information in a more understandable way. Liu (2013) had proposed a faster method to construct the TFM, and it is easier to update and expand the details. Cheng et al. (2013) had construct IPC and USPC as technical words and functional words respectively, it can help designers to quickly construct the TFM without the help of experts. Nanba et al. (2008) had put forward extracting the technology and function in papers and patents at the same time. Tseng et al. (2007) considered the efficiency and effectiveness of creating patent maps, he researched many methods such as: text segmentation, summary extraction, feature selection, term association, cluster generation, topic identification and information mapping. The above experts and scholars pay more attention to the efficiency and visualization of results in the construction of the TFM. The ultimate goal of constructing the TFM is to help managers make decisions on the next technology layout, formulate enterprise development plans, and provide guidance suggestions for winning target customers and occupying the market in advance.

However, the existing methods seldom consider the specific requirement of customers or the specific development status of enterprises when constructing the TFM. Based on the above literature, this paper proposes a method of establishing TFM based on customer requirements and technology life cycle.

2. Customer requirements

In the field of product design, the product expected state means customer requirements. Customer requirements is the starting point and stay-dot of product design. A successful product design is that designers translate customer requirements into product functions accurately, and display the functions to users conveniently in the use process. In order to help technicians design successful products to meet users' needs, it is necessary to understand customer requirements accurately.

Kano model was put forward by Professor Kano (1984) of Tokyo University of Technology in 1984. The model considers that the relationship between user satisfaction and quality attributes is non-linear. It defines three levels of customer requirements: attractive, one-dimensional and must-be. The quality attributes of attractive requirement will not reduce the users satisfaction degree even it is reduced, however, it will significantly increase the users satisfaction degree when it increases; There is a linear correlation between the quality attributes and the users satisfaction degree who belong to the one-dimensional requirement; Users will be very dissatisfied when the quality attributes decreases that belongs to the must-be requirement, and it is not helpful to improve users satisfaction degree even the improvement of quality attributes. Detailed form can be seen Fig. 1.

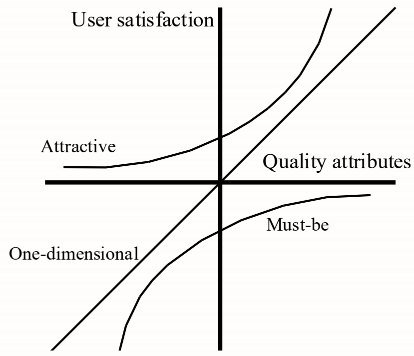


Fig. 1 Kano model's customer requirements

The standard form of Kano model requirements classification table is to set positive and reverse questions. The positive question is the user's feeling when providing this service, and the reverse question is the user's feeling when not providing this service. Both questionnaires have 5 levels: "like", "must-be", "neutral", "live with" and "dislike" for the respondents to choose. Detailed form can be seen Fig. 2.

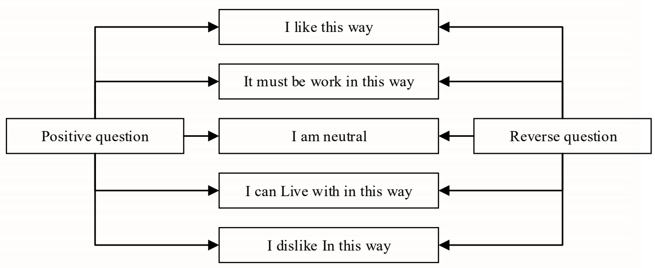


Fig. 2 Positive and reverse questions

The Kano model has some shortcomings, such as low utilization rate of survey data, and it is difficult to categorize requirement types when the number of indicators are the same. In view of these shortcomings, Berger et al. (1993) improved the customer satisfaction index in 1993. On the basis of Kano model, Berger adds an indifferent requirement index. By calculating better-worse index, we can show the impact of a product quality attributes on increasing satisfaction or eliminating dissatisfaction. Berger's formula is as follows:

$$Better=(A+O)/(A+O+M+I) \quad (1)$$

$$Worse=(-1)(O+M)/(A+O+M+I) \quad (2)$$

A=Attractive

M=Must-be

O=One-dimensional

I=Indifferent

The frequency of each type of demand index is determined according to Kano model requirement classification criteria. At the same time, each type of requirement should be determined according to the classification table. R represents reverse requirements. Q represents questions. The Kano model requirements classification table is shown in Table 1.

Table 1 Kano model requirement classification table

		Reverse question				
Positive question	Like	Q	A	A	A	O
	Must-be	R	I	I	I	M
	Neutral	R	I	I	I	M
	Live with	R	I	I	I	M
	Dislike	R	R	R	R	Q
		Like	Must-be	Neutral	Live with	Dislike

By drawing a better-worse quadrant diagram, it can clearly distinguish the type of each requirement. As a basis for the selection of technical blank area in the TFM, technical blank area must be a true reflection of customer requirements. Technical blank areas should not be settled at the point where customers don't care. Clear categorization of customer requirement is an important prerequisite to improve the accuracy of patent layout.

3. Technology life cycle

Tan (2010) have shown that patent technology will generally follow the four stages of technology life cycle development. Four stage life cycle include introduction, growth, maturity, and decline. Each of these four stages has its own development characteristics as shown in Table 2.

Table 2 Stages of technology life cycle

Stage	Feature	Strategy
Introduction	The number of patent applications is small. Technology R&D activities have just started, and the market of product technology is not clear. There are only a few enterprises involved in product production and R&D. Whether the technology can be recognized by the market and whether it is feasible is highly uncertain.	Make full use of the existing components and resources in the system, focus on solving bottleneck technology, and bring products to market as soon as possible.
Growth	With the development of this technology, the product market is constantly expanding. The number of participating enterprises is also increasing, and the number of patent applications is also expanding.	Promote the main products performance to the best and seize the market opportunity.
Maturity	The number of participating enterprises began to decrease gradually. Only a few enterprises were still engaged in relevant researches in this field, and the growth rate of patent applications began to decrease.	Improve product appearance, simplify system. Combining technology with other fields to achieve innovation.
Decline	As the profits of enterprises shrink, enterprises begin to withdraw from the technology market, and the growth of patent applications is negative.	Looking for alternative technologies for new areas and products.

Distinguishing the current development stage of this technology is essential for enterprises to enter this field and improve their products. Through the analysis above, we can see that technology in the stage of growth is easier to occupy the market and obtain higher profits than other three development stages. We need to make a clear judgment on the stage of technology development. In order to accurately identify the technology field at the end stage of introduction or the early stage of growth, it is necessary to be more sensitive and discernible than other competitors. Only in this way, it is easier for enterprises to obtain high returns by combining the characteristics of their own development and choosing technology in the stage of growth.

There are many methods to judge technology life cycle, including S curve method, patent index method, relative growth rate method, technology life cycle diagram method, TCT calculation method (Zhong et al. 2012, Cao 2005, Chen et al. 2006, Lou 2011), etc. Each method has its own advantages and disadvantages. In order to facilitate data acquisition and calculation, this paper chooses the technology life cycle diagram method to judge the technology life cycle.

Generally, the number of patent applications reflect the degree of technological development activities, and the number of applicants reflect the enterprises or individuals involved in technological competition. Using the data of the number of patent applications and the number of patent applicants varying with time, according to the relationship between both, the technology life cycle diagram can be drawn. Detail can be seen in Fig. 3.

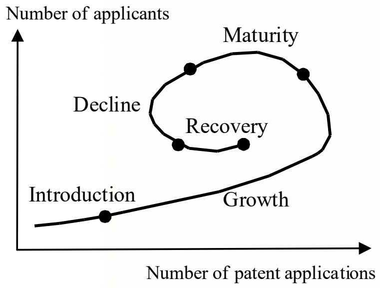


Fig. 3 Technology life cycle diagram

Based on customer requirement acquisition and technology life cycle judgment, a new method to construct the TFM is proposed. The specific process can be seen in Fig. 4.

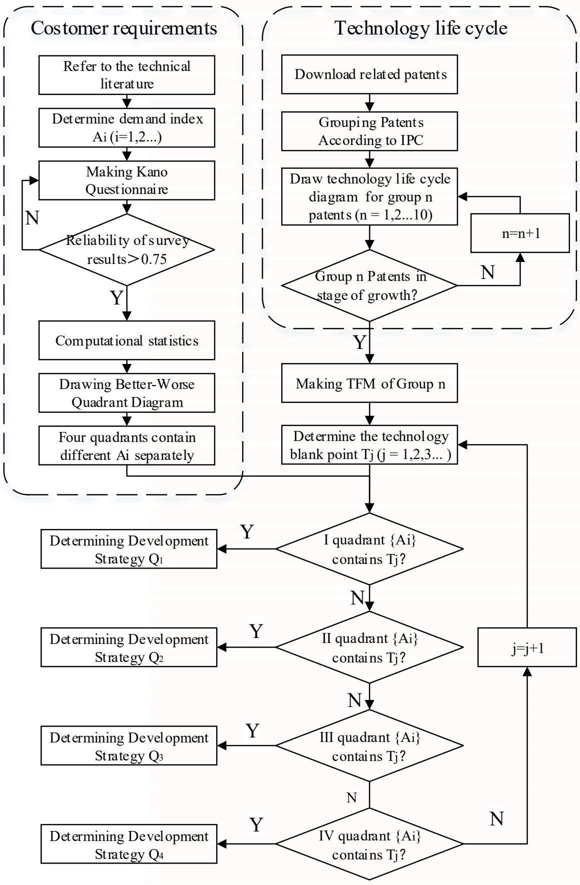


Fig. 4 Establishment of technical - function matrix

Step 1: Acquire customer requirements

Refer to relevant technical literatures and summarize the indexes listed in the literatures describing product performance. According to these indexes, Kano questionnaire was made and the reliability of the survey results was analyzed. The statistical results are calculated, and customer requirements are classified by Berger model. Finally, the quadrant of each requirement index is determined, and each quadrant represents a requirement type.

Step 2: Establish the technology life cycle diagram

Download related patents. Extract keywords for the technology to be analyzed through the analysis of the technology in the stage of growth industry. The key words of technology are input into the patent search software. In this paper, PatSnap are used as the search platform. The extracted keywords are input into the patent search software, and the International Patent Classification (IPC) classification numbers corresponding to the patents are used to screen out the other classification numbers related to the target technology. According to these patent classification numbers, the keywords are expanded, and finally the patent retrieval form is constructed. Only in this way can we ensure that all patents in this technical field can be found out absolutely. At the same time, removal of patents unrelated to the target domain. The specific process can be seen in Fig. 5.

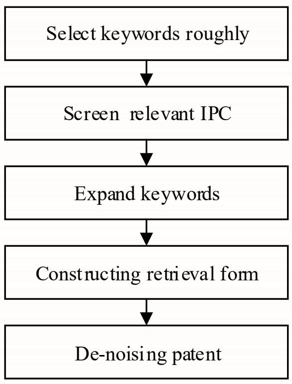


Fig. 5 Patent acquisition process

The key words and IPC classification numbers need to be connected by boolean logic operators in the construction of retrieval form. The specific process can be seen in Fig. 6. The rules for using boolean logical operators are as follows:

(1)The same kind of keywords are connected with each other by the logical relation of "or", which indicates the expansion of keywords with the same meaning.

(2)Different kind of keywords are connected with each other by the logical relation of "and", which means that two types of keywords should appear in a patent at the same time.

(3)The purpose of limiting IPC classification is to remove some patents. It should be connected with the logical relation of "and".

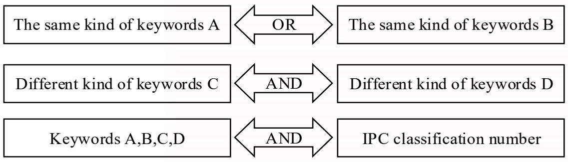


Fig. 6 Boolean logic operators

The downloaded patents are classified according to the subcategory level of IPC classification number. Drawing each subcategory's technology life cycle diagram according to the data of the number of applications and the number of patent applicants varying with time. Patents at the stage of growth are selected as sample patents to construct the TFM.

Step 3: Construct the TFM

The patent texts are labeled "technology" and "function". Technology and function are used as abscissa and ordinate respectively when drawing TFM. Fill in the matrix with the number of patents. Finally, analyses the technical blank area in the TFM.

Step 4: Identifying development strategies

Comparing demand indexes belonging to different categories with technical blank area. Determine the development strategy of all technical blank areas in the TFM.

There are four different development strategies, the meaning of each development strategies can be seen Table 3.

Table 3 The meaning of development strategies

Symbol	Meaning
Q_1	These demand indexes can effectively improve customer satisfaction. There should be at least one such technology in the product.
Q_2	This kind of demand has little effect on the improvement of satisfaction and the decrease of dissatisfaction. Users do not care much about these requirements. When enterprises have limited capacity, they can appropriately reduce their investment in these services.
Q_3	This kind of demand can effectively reduce users' dissatisfaction. This technology belongs to the basic performance of products. When enterprises do not want to expand new markets and adopt a conservative development strategy, they should first meet these indexes.
Q_4	These demands directly affect the improvement of users' satisfaction and the reduction of users' dissatisfaction. Enterprises should pay enough attention to these demands.

4. Case study

Abrasive cutting machine is also called abrasive-disk cutter. Abrasive-disk cutter is suitable for construction, hardware, petrochemical industry, mechanical metallurgy, hydropower installation and other fields. It can cut metal square flat pipe, square flat steel, I-beam, channel steel, carbon steel, circular pipe and other materials. It is a basic and important processing tool in the field of machine processing. The traditional abrasive-disk cutter has the advantages of simple structure, easy assembly, easy portability and low price. Meanwhile, it has some shortcomings, such as heavy weight, high noise and so on. In order to improve the performance of abrasive-disk cutter, many enterprises are committed to the improvement of existing products, it is a key issue how to accurately locate improvement points.

4.1 Customer Requirement Analysis

Data were collected after consulting a large number of literatures about abrasive-disk cutter and visiting consumers and retail customers. A Kano questionnaire with 25 indexes was designed through group discussion and expert consultation, the 25 questions are set up as positive and negative questions according to the standard form of Kano questionnaire. Ask users how they feel when they offered this service or not. Questionnaire design form is shown in Table 4. Fifty questionnaires were sent out and 48 were recovered. 46 questionnaires were valid after screening.

Table 4 Abrasive-disk cutter questionnaire

	Questionnaire	Like	Must-be	Neutral	Live with	Dislike
Positive question	Beautiful display		⊙			
Reverse question	Ugly display					⊙

The reliability analysis was carried out by SPSS software. The result showed that the value of Cronbach's alpha was 0.893. The results of the survey have high reliability, which shows that the questionnaire is reliable. The results of SPSS analysis are shown in Table 5.

Table 5 Reliability analysis

Cronbach's Alpha	Item number
0.893	25

46 questionnaires were collected for statistical analysis. The Better and Worse values are calculated according to formula (1) and formula (2), and the better-worse quadrant diagram is drawn according to the statistical results. The statistical results of the questionnaire are shown in Table 6, and the better-worse quadrant diagram is shown in Fig. 7.

Table 6 Statistical results of the questionnaire

Number	Requirements	A	I	M	O	Better	Worse
1	Beautiful display	8	32	1	5	0.283	0.130
2	Many Product models	2	29	6	9	0.239	0.326
3	Adequate stock	12	23	9	2	0.304	0.239
4	Provide home delivery service	24	13	4	5	0.630	0.196
5	Free installation and maintenance	1	26	11	8	0.196	0.413
6	Payment on arrival	16	25	1	4	0.435	0.109
7	Good service with patience	25	13	7	1	0.565	0.174
8	Familiar with products	7	19	14	6	0.283	0.435
9	Open price	2	16	7	21	0.500	0.609
10	Provide feedback channels	7	31	3	5	0.261	0.174
11	Real-time online consultation	11	29	2	4	0.326	0.130
12	Parts are easy to replace	5	20	9	12	0.370	0.457
13	Easy maintenance	4	23	10	9	0.283	0.413
14	Long service life	21	1	3	21	0.913	0.522
15	Feed controllability of steel pipe	15	22	2	7	0.478	0.196
16	Clamp firmly	8	11	2	25	0.717	0.587
17	Easy to learn and use	13	26	1	6	0.413	0.152
18	Cutting speed is controllable	9	19	4	14	0.500	0.391
19	Easy to replace grinding wheel	7	13	11	15	0.478	0.565
20	Grinding wheel stability	2	1	25	18	0.435	0.935
21	Holistic non-tremor	4	9	18	15	0.413	0.717
22	Operational safety	1	1	16	28	0.630	0.957
23	Beautiful appearance	6	33	2	5	0.239	0.152
24	Cutting a variety of materials	9	22	6	9	0.391	0.326
25	High cutting quality	15	7	18	6	0.457	0.522

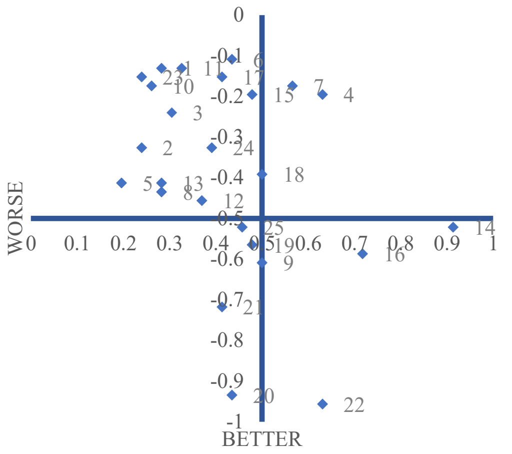


Fig. 7 Better-worse quadrant diagram

Each point in Fig. 7 represents a customer requirement. Better values closer to 1 in quadrant, It indicates that the improvement of this demand index is very effective in improving user satisfaction; Worse values closer to -1 in quadrant, It indicates that the improvement of this demand index is more effective in reducing user dissatisfaction. The name and meaning of each quadrant are shown in Table 7.

Table 7 The name and meaning of each quadrant

Quadrant	Name	Feature
I	Attractive	Better absolute value is high and worse absolute value is low. These indexes have a great impact on improving satisfaction but less impact on reducing dissatisfaction.
II	Indifferent	Better and worse have low absolute values. These indexes have little impact on improving satisfaction and reducing dissatisfaction.
III	Must-be	Better absolute value is low and worse absolute value is high. These indexes have little impact on improving satisfaction but have great impact on reducing dissatisfaction.

IV	One-dimensional	Better and worse have high absolute values. These indexes have a great impact on improving satisfaction and reducing dissatisfaction.

4.2 Product life cycle analysis

The main function of abrasive-disk cutter is to cut cylindrical steel pipe, so the searching key words are "cutting" and "steel pipe". After entering the keywords into the PatSnap Website. Finding synonyms and the same expressions for the initial keywords from the "IPC Classification Number" column. The keywords with the same meaning as "cutting" is grinding; The keywords with the same meaning as "steel pipe" are hard pipe, alloy pipe, thin-walled pipe, metal pipe and rigid pipe. According to IPC classification information, the most relevant IPC classification numbers including "cutting machine" can be obtained: B23K26/38, B23D21/00, B26D7/00, B24B27/00. The final retrieval form is determined as follows through the expansion of above keywords and the de-noising of the IPC classification:

(TAC: (steel pipe or metal pipe or thin-walled pipe or hard pipe or rigid pipe) and ((TAC: (cutting or grinding) and (IPC: (B23K26/38 or B23D21/00 or B26D7/00 or B24B27/00))

The time limit for patent application is 1987-2018. A total of 1085 patents were obtained by retrieval. A further de-noising method is per application only display one open text. Thus, 1001 patents were obtained. These patents are classified according to IPC small group classification. Arrange and analyze the top ten groups according to the number of patents. The technology life cycle diagrams are established respectively based on these patent groups. Classification Number and number of top ten patent applications are shown in Table 8.

Table 8 Classification number and number of top ten patent applications

	Classification Number	Meaning	Number
1	B23D21/00	Machines or devices for shearing or cutting tubes	811
2	B23D33/02	Arrangements for holding, guiding, or feeding Work during the operation	289
3	B23K26/38	Removing material by boring or cutting	143
4	B23D33/00	Accessories for shearing machines or shearing devices	132
5	B23D33/04	For making circular cuts	100
6	B23K26/70	Working by laser beam, Auxiliary operations or equipment	96
7	B23Q11/00	Accessories fitted to machine tools for keeping tools or parts of the machine in good working condition or for cooling work; Safety devices specially combined with or arranged in, or specially adapted for use in connection with, machine tools	70
8	B23D19/00	Shearing machines or shearing devices cutting by rotary discs	58
9	B23Q3/06	For mounting on a work-table, tool-slide, or analogous part.Work-clamping means	45
10	B23Q7/00	Arrangements for handling work specially combined with or arranged in, or specially adapted for use in connection with, machine tools, e.g. for conveying, loading, positioning, discharging, sorting	40

The number of applicants and the number of patent applications are arranged according to the time. And establish the coordinate diagram of the relationship between them. Compare with the technology life cycle diagram standard form in Fig. 3. Determine which stage of the technology belongs to the life cycle. Taking 58 patents under B23D19/00 as an example, the technology life cycle diagram is established. The drawing results are shown in Fig. 8. It can be clearly seen that the curve in Fig. 8 turned backwards in 2018. It shows that the technology of "Shearing machines or shearing devices cutting by rotary discs" is at the end of its growth stage. Even it has entered the early stage of maturity.

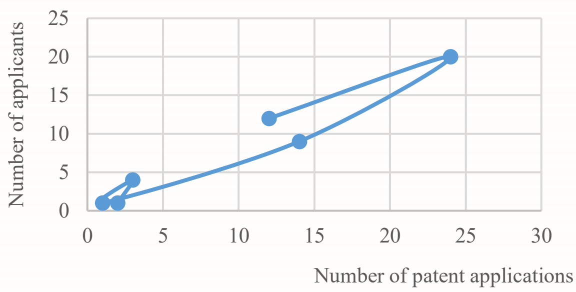


Fig. 8 Technology life cycle of B23D19/00 group

According to the above method, the technology life cycle diagrams of ten technical fields are established one by one. At the same time, the life cycle stage of each technology is analyzed. Finally, it is found that only technical field "For mounting on a work-table, tool-slide, or analogous part. Work-clamping means" is in the early stage of growth of technology life cycle. The technology life cycle diagram is shown in Fig. 9.

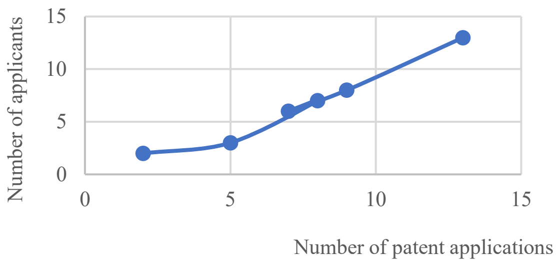
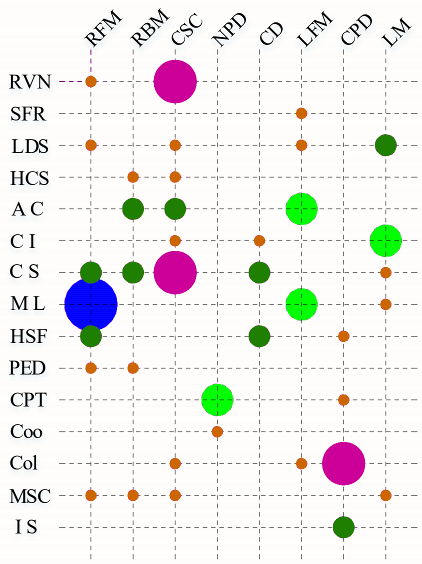


Fig. 9 Technology life cycle of B23Q3/06 group

4.3 Technology-function matrix

According to the analysis in the previous section, 45 patents under B23Q3/06 group are in the early stage of growth of technology life cycle. Choosing the technology in the early stage of growth as the starting point is more conducive to SMEs to improve and develop this technology. Locate the right direction of technology development, push the main performance of products to the best, and seize the market opportunities. By carefully reading the 45 patents under the B23Q3/06 group, we can extract the effects achieved in the patent documents and find the technical means to achieve these effects. Marking the achieved function and corresponding technology, and classify similar technology into a unified expression. Statistics of the number of the same technology to achieve the same function. The technology-function matrix of B23Q3/06 group can be seen in Fig. 10.



RVN: Reduce vibration and noise	RFM: Rotary feed mechanism
SFR: Stable feed rate	RBM: Return baffle mechanism
LDS: Large Diameter Steel Pipe	CSC: Curved surfaces clamping device
HCS: High compressive strength of base	NPD: Negative pressure device
AC: Automatic clamping	CD: Casing device
CI: Clamping invariance	LFM: Linear feed mechanism
CS: Clamping stably	CPD: Collect protective devices
ML: Measuring length	LM: Limit mechanism
HSF: High straightness, Flatness	CPT: Clean processing table
PED: Pipe is easy to displacement	Coo: Cooling and organize
Col: Collect and organize	MSC: Multiple simultaneous cutting
IS: Improve safety	

Fig. 10 Technology-function matrix of B23Q3/06 group

Through the analysis of Fig. 10, it is found that most of the benefits of abrasive-disk cutter patents lie in improving the cutting efficiency and processing quality of steel pipes. To improve the stability of clamping, rotary feed mechanism, return baffle mechanism, curved surface clamping device, casing device and limit mechanism are adopted. The patent layout of this function has been perfected. The abrasive-disk cutter relies on the friction force of the grinding wheel to remove the materials from the steel pipe, and then realizes the steel pipe cutting. In the process of cutting, a lot of heat will be generated, which will cause the burns on the cutting section and inner wall of steel pipe. So it is necessary to reduce the heat generated in the cutting process and improve the cooling effect in order to improve the cutting quality. However, there are few technologies corresponding to improving the cooling effect, which should be the research emphasis in the future.

Through the analysis of the previous section, it is known that the requirement of easy control of feeding belongs to the attractive requirement. Improving attractive requirement can effectively improve customer satisfaction, but as can be seen from Fig. 10, there are few technical means to achieve the effect of "stable feed rate". The technology of improving feed device control has not yet formed an effective patent layout. Technical means to achieve this effect should be focused on.

Operational safety belongs to the one-dimensional requirement, which directly affects the improvement of customer satisfaction and the reduction of customer dissatisfaction. Enhancement of operational safety performance can effectively prevent customer from being unsatisfied, so we should pay enough attention to it. As can be seen from Fig. 10, the intersection point of the function of improving safety and the technology of linear feed mechanism is the technical blank area. The straight-line feeding mechanism moves rapidly, and the workers contact with the steel pipe on the straight-line feeding mechanism directly. It is necessary to further improve this technology in order to achieve the effect of improving safety.

The holistic non-tremor belongs to must-be requirement. Satisfying must-be requirement can effectively reduce the customer dissatisfaction. These demand indexes belong to the basic performance of products. When enterprises do not want to expand new markets and adopt a conservative development strategy, they should first meet these indicators. It can be seen from Fig. 10, the intersection point of the function of reduce vibration/noise and the technology of negative pressure device is the technical blank area. However, it will produce greater vibration and noise when the negative pressure device is running. Therefore, the improvement of negative pressure device to reduce vibration and noise can be regarded as the next research emphasis.

It can be seen from Fig. 10, the intersection point of the function of pipe is easy to handle and the technology of negative pressure device is the technical blank area. The function of rapid positioning of steel pipe by using limit mechanism is remarkable. Although, this effect is easy to achieve from a technical point of view, it is found that automatic steel pipe feeding is an indifferent requirement from the survey of customers. The indifferent requirement has little effect on the improvement of satisfaction and the decrease of dissatisfaction. Users do not care much about these requirements. Therefore, the improvement of the function of easy displacement of pipes can not be the emphasis of research and development. For the 14 indifferent requirements listed in Fig. 7, enterprises with insufficient funds for the production of cutting machines can appropriately reduce their investment in these services.

5. Conclusions

Through questionnaires and customer interviews, the first-hand information of customer requirements is obtained, and these requirements are classified according to the improved Kano model. The classified customer requirements are used to judge whether the direction of patent technology layout is correct.

For small and medium-sized enterprises with weak innovation ability, it is particularly important to choose the technical field in which innovative solutions can be obtained without cross-domain knowledge. According to the characteristics of technology life cycle, technology in the stage of growth is selected as the data for drawing technology-function matrix. After drawing the technology-function matrix, we focus on the technical blank areas, screen these technical blank areas with customer requirements, and further determine the next technology research and development direction.

According to the patent analysis of abrasive-disk cutter, different function improvement methods are adopted for four different requirement types. Finally, the next research emphasis and development direction is determined as follows: easy to control feed, improve safety, and increase holistic non-tremor.

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