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An analysis of factors improving technology roadmap credibility: A communications theory assessment of roadmapping processes

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ABSTRACT

In recent years, many industrial firms have been able to use roadmapping as an effective process methodology for projecting future technology and for coordinating technology planning and strategy. Firms potentially realize a number of benefits in deploying technology roadmapping (TRM) processes. Roadmaps provide information identifying which new technologies will meet firms' future product demands, allowing companies to leverage R&D investments through choosing appropriately out of a range of alternative technologies. Moreover, the roadmapping process serves an important communication tool helping to bring about consensus among roadmap developers, as well as between participants brought in during the development process, who may communicate their understanding of shared corporate goals through the roadmap. However, there are few conceptual accounts or case studies have made the argument that roadmapping processes may be used effectively as *communication* tools. This paper, therefore, seeks to elaborate a theoretical foundation for identifying the factors that must be considered in setting up a roadmap and for analyzing the effect of these factors on technology roadmap credibility as perceived by its users. Based on the survey results of 120 different R&D units, this empirical study found that firms need to explore further how they can enable frequent interactions between the TRM development team and TRM participants. A high level of interaction will improve the credibility of a TRM, with communication channels selected by the organization also positively affecting TRM credibility.

1. Introduction

In an environment of uncertainty and rapid change, it has become imperative for technology-based companies to have a set of resources able to sustain their competitive advantage and core competence. Companies' competences may be understood to flow from the new products and services it can develop through its innovative activities [57]. One of these activities is to establish an effective technology management system [46]. Technology management, in this context, refers to a series of management activities aiming to identify, select, acquire, develop, and utilize technology to maintain a firm's competitive position and performance. These activities should be closely aligned with a company's vision and strategic goals [33].

Among the schemes to identify and project future technologies and to develop further a corporation's core technologies and competences, one of the most widely used in recent years has been known as technology roadmapping, TRM [6,25,37,42,48,51,57]. The technology roadmap approach stands as an effective framework and technique supporting technology forecasting. By utilizing this approach, companies can manage knowledge and information about their business, products, and technologies and establish a

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framework for projecting an effective R&D plan for future technologies in which business and technological points of view are interrelated [16,34,44]. In this way, following the example of consumer electronics companies such as Motorola, Lucent Technologies, and Philips, leading companies in diverse sectors, such as BP, Samsung, LG, Rockwell, Roche, and Domino Printing Sciences, are currently using a technology roadmapping as a key part of an innovation toolkit underlying R&D management and planning [16,38,57]. TRM may also generate effective R&D policies at a national level and has been put to use in such fields as the energy sector, construction, semiconductors and ICT. This phenomenon suggests that individual companies as well as public organizations perceive the importance of TRM as a methodology for maximizing the business effectiveness of R&D activities [56].

Despite these management efforts, it is not always easy to utilize technology roadmaps. In particular, according to the survey conducted by Phaal et al. [44], 50% or more respondents stated that it is difficult to keep the roadmapping process 'alive' on an ongoing basis. Moreover, Lee et al. [57] find that even organizations which have formally adopted TRMs frequently fail to observe the management processes and contents proposed by their maps in their actual R&D activities. This comes about because TRM users are not well aware of the usefulness of the roadmap. In other words, companies are adopting TRMs as a strategic tool for technology management and planning, yet the users, the very people who should utilize it, often resist following a TRM approach, with negative consequences for the degree to which the TRM is used and continuously maintained.

From a similar point of view, Lee et al. [57] have hypothesized that a number of structural and managerial factors as perceived by TRM users may affect the usefulness of roadmap. According to these authors, the 'innovativeness of a development technology' and the 'fixed position of R&D project members' count as structural factors for an organization, and 'fairness of the TRM process' and 'Technology consulting and the degree of education and training' the managerial factors of an organization. However, research on TRMs has not thus far come up with any validated hypotheses for the relation between the quality and utilization, despite work that has attested that such a relation exists [22,41].

If some significant relation exists between the credibility and utilization of a TRM, what are the determinant factors that affect the credibility of a TRM? In previous research, Phaal et al. [47] have argued that a 'clear business need,' 'the desire to develop an effective business process,' and 'having the right people involved and commit[ted],' can be considered as influential factors in TRM utilization. On the other hand, Barker and Smith [15] suggest that 'effectively integrating technology push with business pull,' 'being flexible, capable of generating options and alternatives,' and 'providing information in a manner easily understood by all TRM stakeholders (both developers and users) involved.' all count as essential factors in a TRM's ability to predict future technology needs.

However, these factors were solely derived from either conceptual or case-based research studies, and were not offered on the basis of a theoretical foundation. As yet, no empirical study has been conducted proving the hypothesis that successful roadmapping processes improve the credibility of roadmaps (as perceived by users). More specifically, studies have not taken up the question of what factors need to be considered from the communication point of view in roadmapping. Nor have studies described the effect of these factors on the credibility of TRMs. This is despite the existence of a substantial amount of work proposing technology roadmapping as a communication tool and process for building consensus [7,16,54].

This research, therefore, intends to 1) consider the credibility of TRMs as perceived by TRM users as a factor affecting utilization of TRMs, and 2) to understand how communication in the context of TRMs may further affect perceptions of mapping credibility. The work poses as its research questions:

1. What factors in technology roadmapping affect the credibility of TRMs?
2. Is there a significant causality between these confirmed factors and TRM credibility?
3. Is there causality between improvement in TRM credibility and TRM utilization?

This paper is organized as follows. The next section introduces the concept of TRM through a literature review and describes a theoretical foundation for the factors that will be used to evaluate TRM credibility. Based on this analysis, a number of research hypotheses are specified in Sections 3 and 4, which describe the research model and design. In Section 5, the direct and indirect associations and correlations between model variables are analyzed. Finally, conclusions are presented in Section 6, recommending areas where further research would be beneficial.

2. Literature review

2.1. Technology roadmap

2.1.1. Technology roadmap definitions

Roadmaps exist in various forms according to the situations in which they are developed [15,16,39]. Many kinds of future-oriented documents may be considered as roadmaps [59].

In defining a roadmap, many researchers have focused on describing its functional aspects. From this point of view, Galvin's [42] definition has been the most widely cited: "Roadmaps provide an extended look at the future of a chosen field of inquiry drawn from the collective knowledge and imagination of the groups and individuals driving change in that field. Roadmaps include statements of theories and trends, the formulation of models, identification of linkages among and within the sciences, identification of discontinuities and knowledge voids, and interpretation of investigations and experiments."

Garcia and Bray [34] set out a similar view to Galvin [42], but their concept places a greater emphasis on a TRM as seen from a company's perspective. For these authors, a TRM identifies critical system requirements, product and process performance targets, and technology alternatives that can meet business goals. In that way, TRMs support effective R&D investments. On the other hand, EIRMA [20] argues that each industry has different processes and ways to develop a TRM, but that the essential attributes of these different processes are identical and may be generalized in the schematic form of a standard TRM.

The first TRM factor they suggest is 'time', as shown in Fig. 1. A TRM should have a predictable value. In this way, it should show not only present situations but points of time in the future. TRM's second factor is 'desirable or expected performance characteristics' — the projection of these characteristics is closely related to roadmaps' perception of external influences.

The third factor is the 'classification and interrelationship of technologies considered necessary for a product.' This classification supports the identification of R&D programs that may be appropriately conducted in the future. The fourth factor is the 'identification of the technology, science, and know-how necessary for an R&D program.' Lastly, the fifth factor is the 'identification of the human, intellectual, physical, and financial resources the company can access in moving forward' [20].

2.1.2. Technology roadmapping

From a company's point of view, TRM represents a needs-driven technology planning process that identifies, selects, and develops technology alternatives to meet a series of product demands. These demands determine how the TRM in terms of a final output is produced [34].

The most suitable roadmapping process for any organization depends on the various contingent factors, such as the market, culture, and standard of resources, which it has to deal with, and the contents, range, and characteristics of its specific technology issues [20,39,46]. In other words, there is no specific roadmapping methodology that can be commonly used by all companies in all industries.

However, on a basis of a literature review, Beeton [16] derives four common process phases, made up of 'Planning', 'Insight Collection', 'Insight Processing', and 'Interpretation/Implementation'. This conceptualization classifies phases of roadmapping that perform similar functions, as shown in Table 1.

Moreover, many scholars see the roadmapping process as a communication mechanism for a development team and ultimately for a whole organization [15,16,39,43,54].

Kostoff and Schaller [54] suggest that communication, in fact, is the essence of TRM. They describe that roadmapping integrally involves a social mechanism and accordingly can promote a broader understanding across a company of science and technology

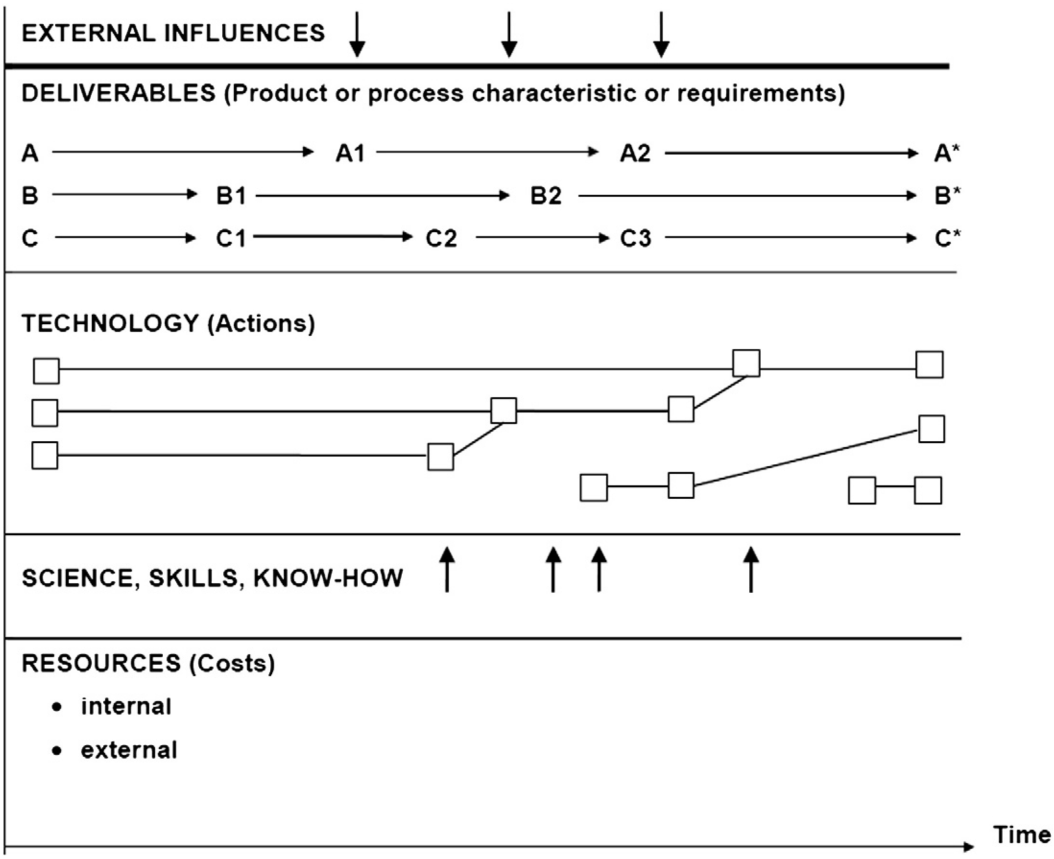

Fig. 1. The TRM framework [20].

Table 1
Phases of technology roadmapping.

Phase	Content
Planning	Establishing and adjusting the purpose, scope, process, and framework of a specific field
Insight collection	Collecting information and knowledge suitable for a field and relevant for an organization
Insight processing	Structuring information and knowledge (including that collected from experts) into a form capable of being shared and distributed
Interpretation/implementation	Continuously monitoring and updating the validity and relevance of information and knowledge with changes in time/situation

development programs. Phaal et al. [43] also refer to the idea that companies need to communicate and manage information effectively, keeping up a close relationship between technological resources and business goals. In this context, they suggest that TRMs can facilitate maintaining the closeness of this relationship. Relevant participants should come together to create a TRM's communication mechanism, so that the TRM can reflect the organization's integrated view of its internal technologies, products, and marketing through mapping's visual dimension.

Beeton [16] explains how the relation between technology roadmapping and communication has been described in previous works from the literature [15,19,39]: “the dialogue and communication necessary in the roadmapping process is probably more important to an organization than the roadmap itself. The process facilitates informed, open and objective discussions and helps people to communicate their plans and visions and to receive feedback on them. This can improve communication both within organizations (e.g. cross-functional, geographical) and also across supply chains (e.g. buyer–supplier relationships, industrial consortia)”.

2.1.3. The use and expected benefits of TRM/technology roadmapping

There are number of previous research works that suggest the benefits of using TRM in private and public sectors (Communication Coordination, Consensus, Decision-making, and Innovation, etc.). The main benefits of TRM (technology roadmapping) referred in all these literatures have to do with improving organizations' ability to plan and make decisions.

According to Garcia and Bray [34] and Beeton [16], one of the major expectations placed on technology roadmapping is that it will offer the information necessary for better decision-making. Further, they indicate that maps should meet this expectation by 1) identifying the gap between a key technology needed to meet a product performance goal and present technologies, and 2) identifying ways to leverage R&D investments through coordinating research activities either within a single company or among alliance members. Another benefit of TRM is that it may generate a framework to plan and coordinate technology or product development. Barker and Smith [15] again describe roadmapping as a flexible and useful approach for suggesting technology alternatives. This characteristic means that it can be readily utilized as a planning and coordination tool [16].

TRMs are further useful in being able 1) to derive a consensus on the technologies that will be necessary to meet demand, and 2) to offer a mechanism for forecasting technology development in terms of product goals for the business [34].

The works referred to above suggest that a company can improve its capability to manage its own technologies by utilizing TRM. Communication between individual job-holders and organizations can further play an important part in the process.

2.2. Berlo's communication theory

Organizations are frequently disrupted by what is known as the ‘communication problem’. Communication problems occur when a gap arises between a message receiver's interpretation and a source or sender's intention. Scholars have developed various models to understand the essence of communication, with the goal ultimately of helping people and organizations to communicate better [40].

In modeling communication, theories have tended to identify the same basic constituents of Message, Source, Encoder, Channel, and Decoder, even though they have approached communication from different point of views. Berlo [18] developed a simple and useful model, known as the Source, Message, Channel and Receiver (SMCR) Model [40], largely through simplifying other schematizations (Fig. 2).

The SMCR model explains the process by which the Source's Message is delivered to its Receiver through a Channel. The source in this context refers to the place where communication originates. The message refers to the contents of communication. The channel is to be understood as a medium used to deliver the Message to an intended Receiver.

These four elements have different attributes. Firstly, the Source includes information, an attitude, and a level of communication skills about the Source that draw on the beliefs available in a socio-cultural context also occupied by the Receiver (who will have similar beliefs). The Receiver Message and Channel include attributes encoding and sending the Message [29]. Differences among these attributes among the factors of communication affect the communication process [18,28].

Further, Berlo [18] suggested that the goal of communication is to affect ‘others,’ the ‘physical environment,’ and ‘ourselves.’ This chimes with Aristotle's definition of communication – of persuading people of a speaker's point of view – which formed the basis of research on the communication model [18].

These four elements of communication, with their attributes, may come together in a bid to improve communication's effectiveness, so that Source can make the Receiver understand his intended Message and duly affect the Receiver's behaviors. The SMCR model and changes in the Receiver's psychology and behavior which result from communication tend to be studied in different disciplines.

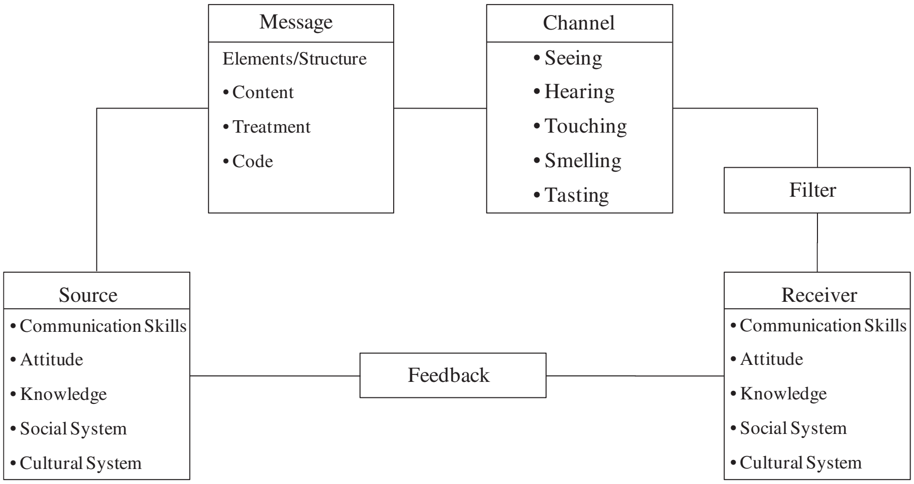

Fig. 2. Berlo's [18] communication model.

A number of research works in Information Systems refer to the idea that received information is used in a way determined by interactions amongst the four elements of the SMCR model and their attributes. On this basis, Moenaert and Souder [52] have studied the communication relationship between the marketing and R&D sectors, information quality and information utilization. They classified staff working respectively in marketing and R&D as a Source and a Receiver and described how various shared attributes had a significant effect on the perceived credibility and utilization of information (the Message). Vandevelde and Dierdonck [3] refer to the fact that a difference of language among team members can affect how the Receiver is perceived. This means that communication can be impaired by language barriers, which represent one of the main obstacles in the way of integrating a firm's design and manufacturing sectors. Further, for Vandevelde and Dierdonck [3], physical factors limiting the Source and the Receiver's communication can also affect information's utilization.

Taking a different line, Byron [29] hypothesizes that the attributes of the Sender (Source), Receiver, and Channel (here E-mail) have a neutral or negative effect on the emotions felt by the Receiver in communicating. This research proves this hypothesis in terms of a basic framework using the SMCR model.

2.3. Summary

TRM combines and aligns a specific product plan with market and technology trends [59]. In this way, roadmapping requires information to be processed and collected about the market, product, and technology and means of integrating these factors [20,45].

A number of TRM research works emphasize how experts with particular knowledge and skills may jointly participate in collecting, processing, and integrating this multidimensional information. Dixon [7] describes roadmapping as a completely integrated process to promoting the participation of the problem owner, solution provider, customer, and other stakeholders. Kostoff and Schaller [54] further describe roadmapping as a tool centrally facilitating communication and learning experiences and including a social mechanism.

In short, in putting together a product plan, TRM may be considered as a series of communication processes, with the final roadmap output being developed through this process.

From this point of view, the theoretical framework provided by Berlo's [18] SMCR model and other later research based on it – centrally involving the claim that 'the elements of the communication process affect the attitude and behaviors of the receiver' – may be plausibly applied in the context of this piece of research.

To make TRM users' perceive roadmap outputs as credible and useful data, a TRM development team should continuously communicate with users. This is because the elements of communication as identified in communication models can be influential in encouraging the utilization of information. If, for instance, TRM users mistrust TRM development members' level of knowledge, it will be difficult for them to credit information offered by the final roadmap output, even if frequent interactions have gone on between TRM developers and end-users. Further, if different participants including TRM members and users, have different knowledge and experiences of technology, a gap in both background and working language can occur between them. The roadmapping process offers a way of dealing with these potential gaps and failures to 'communicate communication'.

3. Research hypotheses development

To derive the factors that influence the use of TRM from a communications perspective, this section develops a number of research hypotheses in order to construct an appropriate research model based on Berlo's [18] communication theory. In focusing on attitudes towards communicating and styles of communication, this research developed six research hypotheses. It proposed these hypotheses making the assumption that variability in communication parameters affected TRM users' perceptions and attitudes. The proposed research model is shown in Fig. 3.

Berlo [18] suggests that the source's attitude can affect the fidelity of communication, classifying stances on the part of the source as an 'attitude toward oneself,' 'attitude toward the subject to [be dealt with],' and 'attitude toward the receiver.' That is, he believes that the source's positive or negative evaluation of him, creditworthiness with a particular subject matter, and favorable or unfavorable attitude toward the receiver affect the effectiveness of his communication and message. Among these three types of attitudes, the 'source's attitude toward himself' is perhaps the hardest for the receiver to assess. In this way, this research focuses more on the sender's (perceived) 'attitude toward the receiver' and 'attitude toward the subject' in hand.

First of all, describing dispositions similar to those characterized by the sender's 'attitude toward the receiver,' Cook and Wall [26] suggest that a person's positive intentions toward others will affect how they treat these people. Giffin [30] says that the source's favorable or unfavorable intention towards others will affect interpersonal trust. Moreover, research on marketing planning, research, and intra-firm communication with other sectors has argued that the source's cooperative attitude toward the receiver has a positive effect on the credibility and utilization of their messages.

In terms of the credibility of information, John and Martin [22] argue that the more individuals' expert knowledge is both diverse and physically adjacent to each other, the more their marketing planning and project output, as mediated by communication, improves. They do not directly refer to 'the source's cooperative attitude toward the receiver,' but imply that credibility of messaging can be improved by the input and mutual cooperation of experts from different but related fields.

Moorman et al. [10] hypothesize that individual employees are more likely to be committed to organizations they perceive to be cooperative than to ones they see as individualistic and competitive. Accordingly employees' trust in a researcher improves when they see this researcher (for instance, in marketing) as being disposed to work cooperatively with them. In terms of communications theory, a source's willingness to cooperate with the receiver is closely related to trust in the source. While Moorman et al.'s [10] research focuses on relations between the source's attitude and the receiver's trust in this source, Gupta and Wilemon [4] devote more attention to the relationship between the source's attitude and the credibility of his message. Their research shows that when R&D members working on a new product development process can credit a marketing manager's cooperative and open characteristics, they come to see the information offered by the marketing manager as more credible.

Together with 'the source's attitude toward the receiver,' the source's 'attitude toward the subject' in hand can also affect the message. These literature findings lead to the following hypothesis:

Hypothesis 1. The stronger a TRM development team's willingness to cooperate with TRM users, the more credible TRM becomes.

According to Barabba and Zaltman's [61] and Zaltman and Moorman's [23] work, a researcher's creative efforts in attempting to reduce the uncertainty attached to his estimations, interpretations and definitions can improve the value of his research, offering end-users important value-added services. In this way, if end-users are impressed by a researcher's willingness to present research results in a way that is clear and specifically meaningful to them, they will trust this researcher more [10]. Furthermore, the more trust in the researcher improves [10] and the more credible his research results also appear [24]. 'A researcher's attitude towards disseminating his research', here corresponds to Berlo's 'the attitude of source toward the subject matter.'

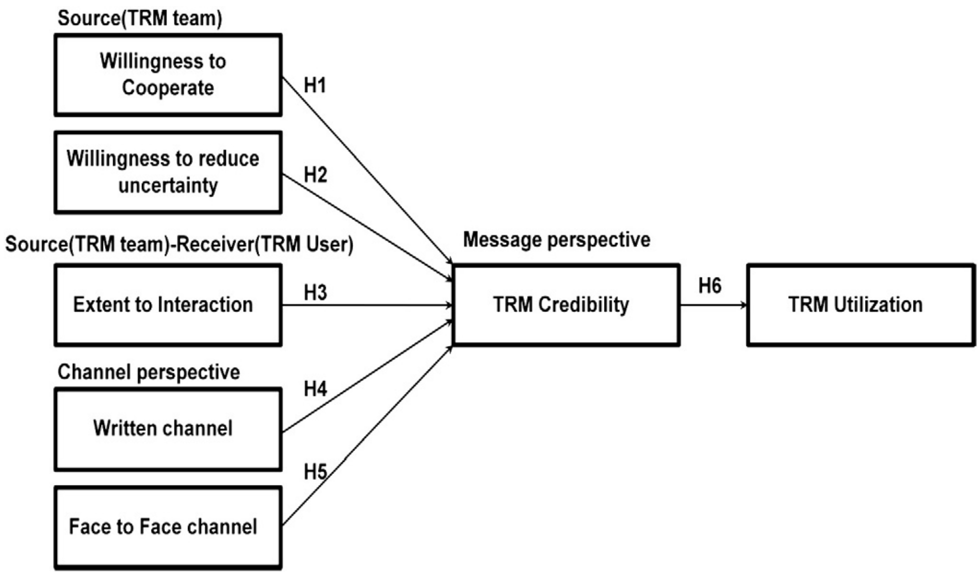

Fig. 3. Proposed research model.

This research background can be applied to the current case to model the relation between TRM members' attitude as perceived by TRM users and TRM credibility. Describing the roadmapping process, EIRMA [20] continuously refers to the importance of TRM members' establishing and maintaining a positive motivation. Beeton [16] also suggests that it is important to establish a persuasive rationale for technology roadmapping during the planning stage of roadmapping, so that TRM users 'buy into' the value of the process and the work of maintaining it. For instance, one of TRM development team's willingness to reduce uncertainty is incorporating more rational and scientific techniques within the roadmapping process. For instance, techniques such as AHP [36] and Portfolio Analysis [58] are used for making a rational decision on priorities in developing future technology while QFD [9,56] and Grid analysis [49] are used for identifying relations between markets, products and technology. All these techniques do not only provide more accurate and clear uncertainty in technology forecasting but also seek to correlate analytical perspectives in solving problems creatively. In this way, this research can formulate the following hypothesis based on the literature referred to above.

Hypothesis 2. The more a TRM development team is willing to reduce the uncertainty associated with TRM forecasts, the more credible a TRM becomes.

In analyzing communication, it is useful to distinguish between a monadic and a dyadic approach. Monadic definitions of concepts cannot consider the relationships between people and objects, but allows the definition of concepts solely from a single point of view. Dyadic definitions explain concepts by looking at the relationships of people (or objects), rather than the intrinsic attributes of these people or objects themselves [18]. For example, defining 'leadership' will only consider a leader's attributes such as intellectual ability and personality, etc. However, a dyadic approach can refer to relevant behaviors connecting the leader to his followers [18].

Based on this distinction, Berlo [18] argues that in analyzing communication both monadic and dyadic approaches to understanding relations between the factors of communication have some value. In particular, dyadic approaches have recognized that frequent interactions between the source and receiver are an important prerequisite for the development of mutual trust [14]. Through frequent interactions and communication, the receiver can observe the source's behaviors and finally becomes better at predicting source behaviors [14].

To extend this point of view further, Moenaert and Souder [52] hypothesize that the intensity of communication among members at the interface of the R&D and marketing sector affects the comprehensibility and credibility of information. As a result of analyzing 386 collected questionnaires from 40 companies from various fields of industry, such as the software engineering, telecommunications, and chemicals sectors, the authors found that the more frequently and fully R&D sources and marketing receivers communicate, the more comprehensible and credible the information they generate together becomes. Similarly, Deshpande and Zaltman's [41] path-analysis determined that a marketing manager's trust in a marketing research agency was also affected by communication factors. The extent of communication, they found, was instrumental in building trust between researchers and receivers, with frequent communication again boosting the credibility of information. TRM emphasizes the social and interactive aspects of sharing information. Put another way, roadmapping offers opportunities for different organizations to communicate, although a critical factor in roadmapping's success is the degree to which roadmaps are continuously maintained [21].

Beeton [16] also emphasizes communication in the roadmapping process. Based on a review of existing literatures, he suggests that the concept of TRM can be classified into, on the one hand, knowledge management and, on the other, technology foresight. First of all, from the point of view of knowledge management, roadmapping can be utilized to exchange both explicit and tacit knowledge and to create new knowledge from these interactions and forms of information-pooling. Further, as a form of technology foresight, roadmapping can be used as a tool to support experts in collecting information about the future more widely. The structure of TRMs can help participants reach a consensus on a specific issue by offering them opportunities to communicate.

For EIRMA [20], the TRM process necessarily draws on a broad team made up of IS/IT employees, executives, staff from other sectors, and external experts. For this paper, executives' participation is necessary to devise major plans, to assess relevant information, and to verify the final TRM, while it can also be important to have representatives or stakeholders from different business functions with appropriate expert knowledge to participate in each stage of roadmapping and continuously to maintain communication with technical experts.

In this way, by expanding on the existing technology roadmapping literatures which refer to the importance of continuous communication and contact among roadmapping participants, this research can suggest the following hypothesis.

Hypothesis 3. The more often the communication between a TRM development team and TRM users, the more credible a TRM becomes.

The channel is an important element in communication, linking the source and receiver through such modalities, for instance, through the senses of hearing, sight and touch [18]. However, relevant research works say different things, in both large and small way, on the subject of channel selection: the ease with which the receiver understands the message for many researchers varies according to the situations in which communication occurs [18].

The majority of communication research argues that comprehension improves when information is communicated in written form [32,53]. However, Moenaert and Souder [53] say close to the opposite in their research, describing how marketing staff preferred interpersonal communications, while the R&D staff preferred the written channel. The authors made the claim that putting communication in writing will improve the validity of information on the basis that receiver will pay closer attention to writing. On the other hand, communicating information in person can make it more comprehensible and emphatic to receivers. In this situation, receivers more quickly pick up tacit knowledge and jargon and can obtain direct responses to questions [53]. Later empirical research, in fact, has not supported the suggestions made by Meonart and Souder, with its turning out that both interpersonal and written channels equally affect the credibility of information [52].

On this topic, Bos et al. [35] conducted an experimental piece of research to compare the influence of the face-to-face channel and a computer-mediated channel (video, audio, and text) in building trust among communication participants. According to their research results, communication through the face-to-face, video, and audio channels turned out to have more positive effects on trust development than communication based just on the exchange of texts.

As suggested above, existing research on communication has suggested mutually exclusive findings regarding the effect of channel type on message, or on the relationship between channel type and the degree of trust in the source established by receivers. To some extent, the same confusion characterizes work on TRM. Even though very few works directly refer to communication between TRM development teams and users, the immediate subject of this study, those that do describe the processes of data and information collection engaged in by TRM participants in a number of potentially conflicting ways. Some previous research underscores the importance of the face-to-face channel through such forms as brainstorming and workshops etc. [16,20,21,47,48]. Others state a preference for using the written channel during roadmapping [6,21,60,62]. In this way, this research can suggest the following two hypotheses:

Hypothesis 4. The more the written channel is used as the main form of communication between the TRM development team and TRM users, the more credible a TRM becomes.

Hypothesis 5. The more the face-to-face channel is used as the main form of communication between the TRM development team and TRM users, the more credible a TRM becomes.

Previous research has also pointed to a close relation between the credibility of information and knowledge created through communication among organizations or individuals and its use. Gupta and Wilemon [4] argue that as the credibility and quality of information improves, so the extent of cooperation between R&D and Marketing as perceived by R&D members likewise picks up. Improvement in cooperation in this context means an increase in the utilization of marketing information by R&D members. Similarly, Moenaert and Souder [53] argue that R&D and the credibility of information perceived by R&D and Marketing members affect the utilization of information.

Other research shows the relation between credibility and the utilization of research reports or outputs. Zmud [50] takes the view that the form in which a report expresses its data is relevant to how well that data is utilized. Weiss and Bucuvalas [11,12] argued that other factors relating to data outputs such as acceptability, realizability, and the quality of information analysis affect utilization. Based on literature in the field of decision sciences, Deshpande and Zaltman [41] have classified the quality characteristics of research results in terms of its form and content, verifying the hypothesis that differences in these parameters affect the utilization of information.

In the same area, John and Martin [22] conducted a research exercise verifying the relation between the structure of an organization's market planning resources (its degree of centralization, formalization and structural differentiation), the credibility of data outputs, and their utilization. As a result, they confirmed that the structure of an organization affects both the credibility of the output and the extent of its take-up. Further, the authors found a close relation between output credibility and its utilization. Applying this relation between credibility and utilization to this research, the following hypothesis may be proposed:

Hypothesis 6. The more TRM users perceived TRM outputs as credible, the more TRM utilization increases.

4. Constructs and measures

This section describes the conceptual definitions, measures and related studies of the seven research variables used in this research.

For independent variables of factors influencing TRM credibility, this study's measurement variables are constructed as based on previous literatures and some measurement items are also shown in Table 2 (detailed questionnaire is also shown in Appendix A).

Zaltman and Moorman [23] suggest that the concept ‘team player’ may designate a researcher's disposition to work to maintain trust with the users of research outputs. Similarly, Moorman et al. [10] derive a variable for researchers' ‘perceived collective orientation,’ denoting a researcher's willingness to cooperate with the users of research products. In short, TRM can be considered as a kind of collective output analyzing and modeling the market, the product in question and technology trends, and deriving suggestions in terms of future foresight. In this way, this research defines ‘willingness to cooperate’ as a TRM development team's willingness to cooperate with users of the roadmapping process as shown in Table 2.

Moreover, an information provider can miss information essential to decision making due to limits in time, resources, and methodology used. Even if sufficient data exists to support a decision, this data can be difficult to interpret securely [23]. To solve this problem, a researcher should try to reduce the uncertainty that attaches to information and findings derived through that information [23]. From this point of view, Moorman et al. [10] derives a variable for ‘willingness to reduce uncertainty,’ denoting a researcher's readiness to interpret unclear suggestions. Similarly, this research defines ‘willingness to reduce uncertainty’ as a TRM development team's willingness to reduce, or seek to clarify, unclear information in TRM.

Table 2
Operational definitions of independent variables.

Variable	Operational definition	Measurement items	Source
Willingness to cooperate	A TRM team's willingness to cooperate with users	TRM teams know when to communicate opinions.	Zaltman and Moorman [23]; Gupta and Wilemon [4]; Moorman et al.[10]
Willingness to reduce uncertainty	A TRM team's willingness to reduce the uncertainty of information/knowledge	TRM teams appropriately and expertly process information based on product R&D teams' situations.	Zaltman and Moorman [23]; Moorman et al.[10];
Extent of interaction	The extent of communication between a TRM team and its users	TRM teams frequently communicate about the TRM with product R&D teams.	Deshpande and Zaltman [41]; McAllister [17]; Moenaert and Souder [52]; Nicholson et al.[14] Joshi et al.[31];
Written channel	The extent of utilization of written forms as the main means of communication \between a TRM team and its users	TRM teams and R&D teams mainly write to each other.	Gerstenfield and Berger [1]; Moenaert and Souder [52,53];
Face to face channel	The extent of utilization of face-to-face forms as a main means of communication between a TRM team and its users	TRM and R&D teams mainly communicate in person.	Gerstenfield and Berger [1]; Moenaert and Souder [52,53];

In addition, those two variables, 'extent [of] interaction' and 'interaction frequency', have more or less the same meaning and are sometimes used interchangeably or in a mixed way in relevant extant research (see [17]). However, there are clear differences between the terms. First of all, the variable 'extent of interaction' refers to perceptions of how frequently contact has been made [14,41]. Meanwhile, 'interaction frequency' refers to the actual frequency or the number of communications and contacts between teams and users. This research intends to inquire into the extent of communication with a TRM development team as perceived by users and accordingly uses 'extent of interaction' as its variable.

Lastly, RoosenBloom and Wolek [55] and Moenaert and Souder [52] classify the channel of communication into the interpersonal channel and the written channel, while Gerstenfield and Berger [1] opt for an oral channel and a written channel. However, in the context of the TRM research, the interpersonal or oral channel is limited to the face-to-face channel in such forms as workshops and brain storming. Based on this, this research classifies the communication channel into the 'face-to-face channel' and 'written channel.' The variable 'face-to-face channel' denotes the extent to which a TRM development team communicate face-to-face or in person as a main form of communication in exchanges with a TRM's users The 'written channel' signifies the extent to which a TRM development team and roadmapping's users predominantly communicate through writing.

The credibility of information involves slightly different characteristics according to the theme, process, and situation of research [2,22]. John and Martin [22] suggest realism, accuracy, specificity, consistency, completeness, and validity as items to measure the perceived credibility of information. Gupta and Wilemon [4] suggest considering whether information is realistic and valid, well-analyzed, well-presented, objective, consistent and complete, useful, and appealing; all these attributes boost information's credibility. Further, Moenaert and Souder [52] suggest validity, timeliness, completeness, clarity, surprise, recency, and accuracy as the factors for the credibility of information.

This research, as shown in Table 3, intends to define credibility from the point of view of believability [13]. That is, the credibility of a TRM may be represented by the extent to which it is perceived as offering credible data by users.

Menon and Varadarajan [2] broadly classify the utilization of information, or research results, into three headings. The first is instrumental use; findings and the conclusions of knowledge or research are applied directly to solve problem. The second is conceptual use; findings not appropriate for a particular concept or incapable of being applied specifically are used to understand a concept or to model a problem. The third is symbolic use; consciously or unconsciously research results are modified or distorted so that they come to have symbolic or symptomatic value.

Utilization of TRMs may directly guide product and technology development activities and decision making, and thus falls under the heading of instrumental use. In this way, the variable 'utilization of TRM' is defined in this research as the extent to which a TRM is actively utilized in a clearly instrumental way, shown in Table 4.

Table 3
Operational definitions of TRM credibility.

Variable	Operational definition	Measurement items	Source
TRM credibility	The perceived believability of the TRM as created by TRM activities	An absence of contradictory foresight information in TRM The TRM's product development planning is based on collected data. The TRM stores data systematically and scientifically.	John and Martin [22]; Gupta and Wilemon [4]; Moenaert and Souder [53]; Moenaert and Souder [52]

Table 4
Operational definition of TRM utilization.

Variable	Operational definition	Measurement items	Source
TRM utilization	The extent of TRM utilization as calculated by technology roadmapping activities	TRM activities and outputs fully contribute to decisions on product R&D projects TRM is used in delivering product R&D projects	Zmud [50]; Deshpande and Zaltman [41]; Ives et al. [8]; Moenaert and Souder [52,53]

5. Data analysis

5.1. Designing an empirical study and data collection method

Based on the proposed research model, which described research hypothesis presented above in terms of constructed variables, this study comprised 29 survey questions as shown in Appendix A. Fifteen questionnaire items inquired into factors influencing TRM credibility (15), five into TRM credibility itself (5), four into degree of TRM utilization (4) and five sought out demographic information (5). The demographic information included the respondent's position and length of employment at the firm; the firm's annual R&D expenditure; its annual R&D expenditure against sales; the firm's industry, and respondents' purpose in referring to TRMs. All constructs were measured using a 7 point Likert-style scale with item answers ranging from strongly disagree (1) to strongly agree (7).

5.2. Demographics and descriptive statistics

The sample of this research is companies that are developing TRM and which utilize it amongst their product R&D teams. This study surveyed companies listed on the KOSPI/KOSDAQ indices that had engaged in technology strategy development. To limit the sample to companies large enough for consideration, KOSDAQ-listed companies whose assets are valued lower than KRW 50 billion were excluded from the study, while all companies listed on KOSPI were initially considered. The unit of analysis is the leaders of product R&D teams, who had the opportunity to draw on TRM in their product planning. By observing these inclusion criteria, a primary list of 95 firms was surveyed and collected. By talking to different R&D units of the same firm but serving different business domains, the number of samples collected in our final list of respondents was 150. The research method consisted of eliciting answers from responses both over the web and in face-to-face interviews. A total of 120 samples were collected with a response rate of 76.9%. Since there was no response error, all collected samples were analyzed in this study.

The characteristics of the selected sample group, as shown in Table 5 were distributed across a number of industries, including Electronics, IT services, Chemicals, Heavy Industry and Telecommunication. In particular, Electronics and IT service are featured heavily in the study on account of the characteristics of the Korean economy and export sector. Most R&D managers had worked between 2 and 20 years at their firm. The majority of the respondents' annual product R&D budgets were under 50 billion KRW (60% of the sample). Most respondents' R&D expenditure as a proportion of sales ranged from 1.1 to 3.0% (62%). When surveyed on their multiple reasons for using TRM, most respondents responded that they had been interested in changes in the market, products and technology. 25.5% had wanted to identify potential technologies and 19.3% had been concerned to plan a detailed schedule of a R&D project. 12.9% wanted to understand their company's vision and strategy. However, there was relatively lower response rate for the desire to utilize TRM itself as a tool to communicate with other business units.

5.3. Reliability analysis/validity of measurement instrument

Prior to verifying the research model and the hypotheses presented in this research, the reliability and validity of the survey items used in this research were verified. First, to check the reliability of the survey items covering potential factors, SPSS 12.0 was used to check the internal consistency of survey items. Reliability is a form of internal consistency among items; it assesses the extent to which the real measured value of a measurement variable can be measured. This research uses Cronbach's Alpha Coefficient to measure the reliability in terms of the accuracy and precision of the measurement instrument taking together the analysis of several items about a construct.

In general, an Alpha Coefficient of 0.60 and over means that study can be accounted as reliable [27]. The reliability in this research turned out to be very high at 0.80 and over, suggesting the respondents responded reliably to the items as shown in Table 6.

5.4. Validity of measurement variable

Validity is measured on an index showing how accurately a developed tool measures a concept or attribute. This research conducted an exploratory factor analysis to verify construct validity. In particular, it used the principal components analysis method to minimize losses of information by minimizing the number of factors, further using a varimax method of orthogonal transformation as a way of effecting rotation. In terms of deciding the number of factors, this research chose factors whose eigen values were 1 and over, judging that factor loading (the value showing the correlation between each variable and factor) was

Table 5
Respondents' descriptive statistics.

Range	Frequency	Percent
(a) Industry		
Electronics	47	39.1
IT services	45	37.5
Oil/chemical	14	11.7
Heavy industry	8	6.7
Telecommunication	6	5
Total	120	100
(b) Annual product R&D budget (billion, KRW)		
Over 200	10	8.3
150–200	8	6.7
100–150	10	8.3
50–100	19	15.8
10–50	27	22.5
Below 10	46	38.3
Total	120	100
(c) Annual product R&D budget of total revenue (%)		
0.1–below 0.5	16	13.3
0.5–below 1.0	14	11.7
1.0–below 2.0	25	20.8
2.1–below 3.0	39	32.5
3.0–below 4.0	11	9.2
4.0–below 5.0	2	1.7
5.0–below 6.0	4	3.3
Over 7.0	9	7.5
Total	120	100
(d) Number of working years		
Less than 2 years	4	3.3
2 years or more–less than 5 years	20	16.7
5 years or more–less than 8 years	21	17.5
8 years or more–less than 10 years	20	16.7
10 years or more–less than 15 years	29	24.1
15 years or more–less than 20 years	17	14.2
More than 20 years	9	7.5
Total	120	100
(e) Objectives for using TRM (multiple selection)		
Identifying current trends of market, products and technology	92	34.8
Identifying potential technologies	70	26.5
Planning detailed R&D project schedule	51	19.3
Understanding Company's vision and strategy	34	12.9
Communicating with other business units (e.g. marketing, manufacturing)	17	6.4
Total	264	100

significant at values of 0.4 and over [5]. Factor analysis characteristically requires a high correlation between factors. The Kaise–Mayer–Olkin (KMO) measure and Bartlett's test of sphericity are methods showing whether or not items in use are appropriate for factor analysis by confirming the correlation matrix among items. KMO shows the extent to which the correlation between variable pairs is well-explained by other variables. In the terms of this method, a low value for a measure means variable selection for factor analysis must be accounted poor. Generally, a KMO value of 0.90 or above denotes a very good correlation, and a value of below 0.50 means the degree of correlation is unacceptable.

5.4.1. Validity analysis of independent variables

Table 7 shows the result of factor analysis on 15 items testing for independent variables. First of all, Bartlett's identity matrix check gave $\chi^2 = 1955.517$ ($p < 0.01$), showing a sufficient degree of correlation for variables to form a factor. KMO's measure of

Table 6
Reliability of measurement instrument.

Factors	Number of item	Cronbach's α coefficient
Willingness to cooperate	3	0.910
Willingness to reduce uncertainty	3	0.929
Extent of interaction	3	0.910
Written channel	3	0.952
Face to face channel	3	0.928
TRM credibility	5	0.877
TRM utilization	4	0.964

Table 7
Exploratory factor analysis results of independent variables.

Measurement item	Component (factor loading)				
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Willingness to reduce uncertainty 2	0.859	0.138	0.147	0.328	0.199
Willingness to reduce uncertainty 3	0.852	0.213	0.048	0.239	0.276
Willingness to reduce uncertainty 1	0.758	0.151	0.011	0.330	0.364
Written channel 3	0.093	0.937	0.045	0.096	0.138
Written channel 2	0.139	0.933	−0.064	0.164	0.134
Written channel 1	0.209	0.895	−0.155	0.198	0.085
Face to face channel 2	0.054	−0.017	0.962	0.026	0.019
Face to face channel 3	0.064	−0.054	0.958	0.030	0.029
Face to face channel 1	0.077	−0.071	0.849	0.243	0.142
Extent to Interaction 2	0.351	0.150	0.16	0.838	0.249
Extent to interaction 1	0.389	0.261	0.042	0.778	0.298
Extent to interaction 3	0.377	0.280	0.235	0.711	0.286
Willingness to cooperate 1	0.366	0.215	0.059	0.299	0.766
Willingness to cooperate 2	0.485	0.203	0.142	0.371	0.669
Willingness to cooperate 3	0.530	0.137	0.134	0.318	0.640
Eigen value	3.188	2.922	2.744	2.551	1.991
Variance%	21.256	19.480	18.293	17.009	13.273
Cumulative%	21.256	40.736	59,029	76.037	89.310

KMO = 0.867, Bartlett's test result $\chi^2 = 1955.517$ (df = 105, $p < 0.01$).

sampling adequacy check gave a KMO value 0.867. The Common features check also satisfied the factor analysis assumption of measurement data. These led to the following factor analysis deriving a total of five factors and giving factor names based on the main concept of the items composing each factor.

5.4.2. Validity analysis of TRM credibility

Table 8 shows the results of a factor analysis on the five items concerning TRM credibility. First of all, Bartlett's identity matrix check gave $\chi^2 = 344.544$ ($p < 0.01$), showing a sufficient degree of correlation for variables to form a factor. KMO's measure of sampling adequacy gave a KMO value of 0.853. The communality check also satisfied the factor analysis assumption of measurement data.

5.4.3. Validity analysis of TRM utilization

Table 9 shows the results of factor analysis on four items of TRM utilization. First of all, Bartlett's identity matrix check gave $\chi^2 = 646.409$ ($p < 0.01$), showing enough correlation for variables to achieve/form a factor. KMO's measure of sampling adequacy check gave a KMO value 0.759. The communality check also satisfied.

5.5. Research hypotheses testing

This research verified the relation of each previously suggested variable by conducting a correlation analysis; it also checked the causality of each variable by conducting a simple and multiple regression analysis to analyze the relationship among the independent variables and with constructs for TRM credibility and utilization.

5.5.1. Correlation among variables

The result of the analysis on correlation among variables is shown in Table 10. This research found that independent variables observed a directly proportionate relationship to TRM credibility and utilization credibility to utilization ($p < 0.01$).

Table 8
Exploratory factor analysis results of TRM credibility.

Measurement item	Component (factor loading)
	TRM credibility
TRM credibility 3	0.888
TRM credibility 1	0.882
TRM credibility 5	0.861
TRM credibility 4	0.859
TRM credibility 2	0.635
Eigen value	3.448
Variance%	68.964
Cumulative%	68.964

KMO = 0.853, Bartlett's test result $\chi^2 = 344.544$ (df = 10, $p < 0.01$).

Table 9
Exploratory factor analysis results of TRM utilization.

Measurement item	Component (factor loading)
	TRM utilization
TRM utilization 2	0.959
TRM utilization 4	0.957
TRM utilization 1	0.946
TRM utilization 3	0.941
Eigen value	3.615
Variance%	90.380
Cumulative%	90.380

KMO = 0.759, Bartlett's test result $\chi^2 = 646.409$ (df = 6, $p<0.01$).

5.5.2. Hypothesis testing

This research conducted a multiple regression analysis to verify the effects of its independent variables on TRM credibility as shown in Table 11. The explanatory power of the regression model came in at 77.7%, and the regression equation turned out to be statistically significant ($F = 84.119$, $p<0.01$). Moreover, TRM credibility is significantly in direct proportion to Willingness to Cooperate, Willingness to Reduce Uncertainty, and Extent of Interaction ($p<0.05$). Willingness to Cooperate, Willingness to Reduce Uncertainty, and Extent to Interaction ($p<0.05$) further have significantly positive (+) effects on TRM credibility. It turned out that an improvement on Willingness to Reduce Uncertainty raises TRM credibility by 0.524, Extent of Interaction by 0.198, and Willingness to Cooperate by 0.180.

5.5.3. Relations between technology roadmap credibility and utilization

This research conducted a simple regression analysis to verify the effects of TRM credibility on utilization (Table 12). The explanatory power of the regression model was 69.3%, and the regression equation was analyzed as statistically significant ($F = 269.815$, $p<0.01$). TRM credibility has positive (+) effects on TRM utilization. It turned out that improvement in TRM credibility causes TRM utilization a rise in 0.834.

6. Discussion

This research was conducted to enquire into the effects of TRM team members' attitude and perceived communication styles in the context of the TRM process on TRM credibility. It also looked into the relationship between TRM credibility and utilization. As a result, out of the proposed six research hypotheses, four hypotheses (Hypotheses 1, 2, 3, and 6) were accepted, while two hypotheses (Hypotheses 4 and 5) relating to the communication channel were rejected.

Firstly, it turned out that perceived TRM credibility affects TRM utilization. That is, the more users perceive the TRM as yielding a credible output, the more they actively utilize it. Existing research that has verified the relationship between the credibility and utilization of information/knowledge or research outputs support the results of this research [22,52].

The research also found that TRM team members' willingness to reduce uncertainty affects TRM credibility relatively more than other factors. That is, as TRM users credit team members' with being willing to draw on their experience and know-how in analyzing and interpreting collected data and information, TRM credibility improves. This empirical result is supported by Moorman et al.'s [10] research showing that a willingness to reduce the uncertainty of research results affects trust in a researcher, and with Nguyen and Masthoff's [24] research finding that trust in a researcher (a source) finally affects the perceived quality of a research product (the message).

In the TRM process, TRM development team members' willingness to cooperate with users turned out to have positive effects in improving the credibility of final outputs. This contrasts research results of Moorman et al. [10], which suggest that there is no relationship between researchers' willingness to cooperate with the users of research products and the degree of trust they attract.

Table 10
Verification of correlation among variables.

Factors	Communication					TRM credibility	TRM utilization
	Willingness to cooperate	Willingness to reduce uncertainty	Extent of interaction	Written channel	Face to face channel		
Willingness to cooperate	1						
Willingness to reduce uncertainty	0.818**	1					
Extent of Interaction	0.778**	0.749**	1				
Written channel	0.414**	0.390*	0.453**	1			
Face to Face channel	0.230*	0.180*	0.270**	−0.074	1		
TRM credibility	0.802**	0.855**	0.775**	0.435**	0.229**	1	
TRM Utilization	0.731**	0.738**	0.720**	0.429*	0.223**	0.834**	1

* $p<0.05$.
** $p<0.01$.

Table 11
Independent variables' effects on TRM credibility.

Construct	Unstandardized coefficient		Standardized coefficient	t	p	F	R^2	Multicollinearity test
	B	Error	B					VIF
(Constant)	0.373	0.302		1.234	0.220	84.119**	0.777	
Willingness to Cooperate	0.159	0.074	0.180	2.149*	0.034			3.769
Willingness to reduce uncertainty	0.458	0.069	0.524	6.613**	0.000			3.359
Extent to Interaction	0.179	0.069	0.198	2.610*	0.010			3.074
Written channel	0.068	0.049	0.069	1.379	0.170			1.347
Face to Face channel	0.045	0.046	0.045	0.969	0.335			1.147

Dependent variable: TRM credibility.
* $p<0.05$.
** $p<0.01$.

This divergence might be explained by the gap between the way in which general researchers, on the one hand, and TRM development members, on the other, are seen. Further, the perceptions in this research of TRM developers are those of the users of TRM outputs. In Moorman's work, users perceive general researchers as scientists, people whose primary knowledge and ability enables them to undertake a whole process of collecting and analyzing data and deriving suggestions from it [10]. However, TRM development team members were expected by this study's respondents to serve not only as information technicians but also as ‘facilitators,’ as persons ‘responsible for supporting and managing harmonious communication’ among the participants of the TRM process [16,20]. In other words, TRM teams need to actively cooperate with participants at the same time performing researchers' general roles. The study shows that, in these terms, willingness to cooperate with TRM users affects TRM credibility.

Moenaert and Souder [52] and Deshpande and Zaltman [41] have argued that the more different individuals or organizations communicate openly and frequently, the more the quality of research products improves. This research arrives at a similar finding. That is, it turns out that frequency of contact between TRM users was associated with improved TRM credibility.

On the other hand, the ‘written channel’ and ‘face to face channel’, designating the two main communication formats between TRM development team members, turned out not to have any effect on TRM credibility. This result suggests that frequent interchanges between TRM team members and users can have an important effect on TRM credibility regardless of the communication channel utilized in the TRM process. Moreover, research needs to consider again the relationship between the choices of ‘written’ or ‘face to face channel’ vis-à-vis comprehensibility. Moenaert and Souder [52] and Porter and Roberts [32] found that use of the written channel affects the comprehensibility of information, while Moenaert and Souder's research [53] argues that a close relationship between the face to face channel and comprehensibility of information. Putting this literature together, it seems plausible that the two channels of communication examined in this research could turn out to have a significant bearing on TRM comprehensibility, rather than on TRM credibility.

In short, this research study indicates the importance of TRM developers' engagement with other participants, i.e. with TRM users. However, simply setting up a particular communication channel, whether face to face or in a written form, during the roadmapping process is sufficient to increase TRM credibility. Rather, frequent interaction, or the frequent passing of messages in Berlo's [18] language, will contribute to developing a level of mutual trust between the source (TRM developers) and receivers (TRM users); these communication partners will be able to determine what channels or formats of communication to use. Moreover, different communication channels will be appropriate for different organizations, and a customized roadmapping process can design its own communicative mechanisms to meet a business's specific needs.

7. Conclusion

This research is the first study to conduct an empirical analysis of the sub-field of technology roadmapping on the basis of classical communications theory. It contributes to the academic world in offering basic knowledge that can help to make roadmapping more effective in the future. Further, companies can utilize this research as a guideline in better selecting and training TRM members and in more effectively managing technology roadmapping processes.

Table 12
Effects of TRM credibility on utilization.

Construct	Unstandardized coefficient		Standardized coefficient	T	p	F	R2	Multicollinearity test
	B	Error	B					VIF
(Constant)	0.397	0.291		1.364	0.175	269.815**	0.693	
TRM credibility	0.918	0.056	0.834	16.426**	0.000			1.000

Dependent variable: TRM utilization.
** $p<0.01$.

Considering the fact that roadmapping is an iterative process, there is a possibility that TRM utilization, the dependent variable of this research, will also have an effect on other variables. For example, even if users are not satisfied with TRM credibility at first, their response can become more positive as they utilize the updated outputs of a TRM. In this way, future research can consider changes over time in roadmap utilization, for example by evaluating 'technology roadmap periods' or 'the number of times of TRM updates' as a variable.

Further, this research did not fully consider several contingent variables such as the sample companies' industrial, policy and environmental characteristics. This is because the limited number of companies utilizing TRM makes it difficult to collect a sufficient amount of samples when attempting to assess these contingency variables. In the future, if this problem of sample size can be solved, contingency variables can come to feature in research works, and new variables or environmental characteristics specific to an environment or particular business task could also be suggested and analyzed.

Secondly, it would be interesting to find out the relative importance of independent factors in increasing roadmapping credibility from practitioners' point of view. This would help practitioners to focus their efforts appropriately in working to increase credibility: to what degree should they co-operate with users? To what degree should they seek to reduce uncertainty? To what degree should they communicate more? Future work attempting to assign the relative importance of these factors could be carried out through a number of comparative case studies, which would seek to understand control variables and to analyze different situations of TRM usage.

Thirdly, the proposed research model could be re-specified to explore the emergent use of social networking and Web-based forms of collaboration in TRM systems. This work would serve to test the robustness of the paper's framework in the sense of determining whether these emerging communication methods could be used within the terms of the framework to enhance roadmap credibility.

Finally, additional research on the relationship between the type of communication channel and TRM is necessary. As stated above, in this research, it turned out that the communication channel bore no relation with TRM credibility. Further work on the two channels and on the comprehensibility (or some related characteristic) of TRM should be able to suggest how the format of communication relates to the utilization and success of TRMs.

Appendix A. Questionnaire

Part 1: TRM (technology roadmap) level 1 questionnaire.

No	Statement
1	A TRM development team is cooperative.
2	A TRM development team shows a flexible attitude in reflecting my demands (such as opinions of the content, form, and timeline that should be added to TRM) on a roadmap output
3	A TRM development team knows well when to express its opinion and when to reflect my opinion.
4	A TRM development team reflects its own experiences to customized collected data to fit for product R&D team's requirements.
5	A TRM development team reflects its own experience to utilize collected data to forecast the future demand and make an appropriate plan that is suitable for an organization,
6	A TRM development team reflects its own experience to convert collected data into information that is suitable for a roadmap output.
7	A TRM development team frequently tries communication about a TRM product with a product R&D team.
8	A TRM development team and product R&D team frequently communicate with each other during the process of developing TRM.
9	Formal/informal communication is frequently made between a TRM development team and product R&D team during the process of developing TRM.
10	A TRM development team and product R&D team mainly utilizes the written form (such as online/offline surveys) of communication to address major issues that occur in the process of developing TRM.
11	A TRM development team and product R&D team communicate with each other through a written form in the process of developing TRM.
12	Communication between a TRM development team and product R&D team is mainly made by a written form in the process of developing TRM.
13	A TRM development team and product R&D team mainly utilizes the face-to-face form (such as workshops and brainstorming) of communication to address major issues that occur in the process of developing TRM.
14	A TRM development team and product R&D team communicate with each other through a face-to-face form in the process of developing TRM.
15	Communication between a TRM development team and product R&D team is mainly made by a face-to-face form in the process of developing TRM.

Part 2 TRM (technology roadmap) level 2 questionnaire.

No	Statement
1	TRM output is credible.
2	No conflicting future forecast information exists in a TRM output.
3	Information derived from TRM for product development planning is based on empirical data.
4	Methods to collect information/data for TRM are systematic and scientific.
5	TRM mostly includes major issues that are related to a product development plan.

Part 3 TRM (technology roadmap) level 3 questionnaire.

No	Statement
1	TRM output is sufficiently utilized in order to make a decision on a product R&D project.
2	TRM output is sufficiently utilized during the process of a product R&D project.
3	TRM output is actively referred by our organization/team for addressing major issues that occur in the process of a product R&D project.
4	TRM output is actively referred by our organization/team for achieving a product R&D project success.

Part 4 Questions on general information
Directions: This part asks questions about the respondent's general information.

1. How many years have you worked at your current workplace?
   ① Less than 2 years
   ② 2 years or more–less than 5 years
   ③ 5 years or more–less than 8 years
   ④ 8 years or more–less than 10 years
   ⑤ 10 years or more–less than 15 years
   ⑥ 15 years or more–less than 20 years
   ⑦ More than 20 years
2. How much is your company's annual budget for product R&D?
   ① Less than 10 billion KRW
   ② 10 billion or more–less than 50 billion KRW
   ③ 50 billion or more–100 billion KRW
   ④ 100 billion or more–less than 150 billion KRW
   ⑤ 150 billion or more–less than 200 billion KRW
   ⑥ More than 200 billion KRW
3. This question is about your company's annual budget allocation for R&D. Annual R&D budget = ( )% of the total annual revenue

① 0.1%–0.5%	② 0.6%–1.0%	③ 1.1%–2.0%
④ 2.1%–3.0%	⑤ 3.1%–4.0%	⑥ 4.1%–5.0%
⑦ 5.1%–6.0%	⑧ 6.1%–7.0%	⑨ More than 7.0%

4. What is your company's purpose of using a TRM? (Multiple choices allowed)
   □ To predict current trends of the market, product, and technology
   □ To project the future of the market, product, and technology
   □ To make a plan for a project that is currently working in progress
   □ To understand the strategy and vision of a company
   □ To communicate with other business units or teams
5. What is your company's business area? ( )

①Finance/banking	② Communication	③ Petroleum/chemical
④ Electric/electronic	⑤ IT	⑥ Construction
⑦ Still manufacture	⑧ Public, state-run company	⑨ Retail/logistics
⑩ Heavy industry	⑪ Other ( )	

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